Single Channel Radio Control

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SINGLE CHANNEL RADIO CONTROL

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CHAPTER I

What is Radio Control ?

THE primary function of any radio control system is to act as a switching device, nothing more or less. The basic components involved are a transmitter, receiver and an actuator. The transmitter and receiver are connected by a radio link so that any signals switched or keyed at the transmitter end are received and translated into a similar switching action by the receiver. This, in turn, controls the action of the actuator, providing the force of muscle power to move the control surfaces on the model.

Electronic principles are involved solely with the transmitter and receiver design. The actuator is an electro-mechanical device quite separate from the radio side. The transmitter-receiver link could equally well be replaced with a couple of wires connected to a switch, thus controlling the on-off action of the actuator directly. Obviously, however, such a simple hook-up has many disadvantages and is completely impractical for true remote control—hence the necessity for the transmitter-receiver combination and its radio link to dispense with direct physical connection. The main point, however, is that the basic action of the transmitter-receiver link is no more complicated than that of the two wires connecting to a control switch and modern radio control equipment has been developed to the stage where no knowledge of electronics is required to operate it successfully. Tuning and adjustment is simple, following manufacturer's instructions, and subsequent operation reliable enough to regard the receiver as nothing more than a simple switch responding to and following exactly manual operation of the transmitter key or switch.

The whole treatment of the subject in this present book is based on this premise. It is not concerned with circuit diagrams and the theory of transmitter and receiver design, but merely with the manner in which they work as remote control switches. Far more important for the purpose of successful radio control of models is the best application of actuator systems and a working knowledge of elementary adjustments, etc., which are necessary for setting up the complete system. For this reason we need regard the transmitter and receiver as little more than boxes which provide a certain switching action.

Switching provided may be simply on-off—or rather more complex where the switching signal is sent in a series of pulses which can be varied in proportion. Quite the majority of all single channel radio control is accomplished with simple on-off switching but pulse systems can be used with single channel equipment to provide a more sophisticated type of control response. A full description of these is subject for a further book, although some are mentioned briefly in this present volume.

At this stage, I have also introduced a new term—single channel. Briefly, this means a single signal system (see Fig. 1)—although this is not an exact

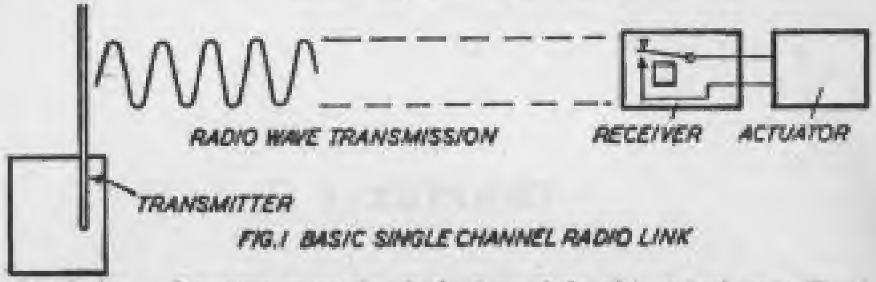


FIG. 1 BASIC SINGLE CHANNEL RADIO LINK

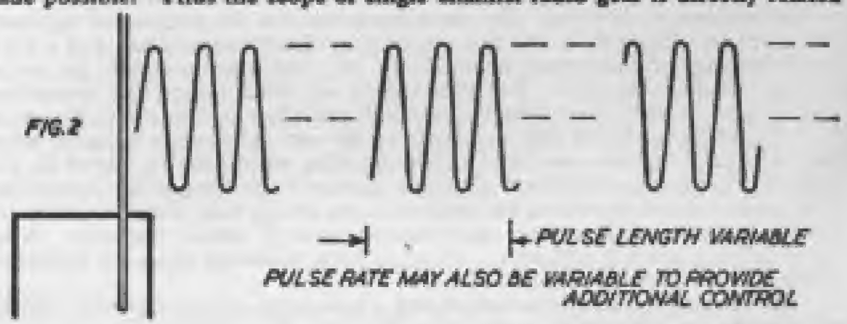
description. A system where the single channel signal is pulsed, as in Fig. 2, can provide more than one signal response by varying both the amplitude and spacing of the pulses. This is still regarded as a single channel system, however, although no longer simple single channel.

There is also another type of transmitter-receiver combination where the radio link is not a continuous (or pulsed) radio wave switched on and off for signalling, but superimposes a tone signal on a continuous or carrier radio wave which is transmitted all the time. Only the superimposed tone is switched on and off to provide the signalling link, the receiver being designed and adjusted to pick up this tone signal (Fig. 3). It has certain specific advantages, notably the ability to respond to lower transmitter power.

Equipment designed to pick up and respond to just one tone signal superimposed on a continuous carrier wave is still single channel since there is only one switching channel available. It is possible, however, to transmit several tones independently on the same carrier and arrange the design of the receiver so that it can respond to each with a separate switching action. In effect, the receiver then has a number of separate switching circuits which can control separate actuator circuits, each responding to one particular tone (or controlled by a pair of tone signals). Anything up to 12 separate tone signals can be accommodated in this manner, leading to what is termed multi-channel operation. These, again, are outside the subject of the present book.

Types of single-channel receivers and transmitters are described in Chapters II and III, respectively. Although in their simplest, and most usual, form they provide only simple on-off switching, they are not necessarily restricted to a single control movement. Using the simplest type of actuator, for example, they usually provide two control movements, one one way and the other in the opposite direction, in sequence. Further independent control operation can be provided by modification of the actuator design and/or combining two or more actuators. Selective control operations can also be made possible. Thus the scope of single-channel radio gear is directly related

FIG. 2



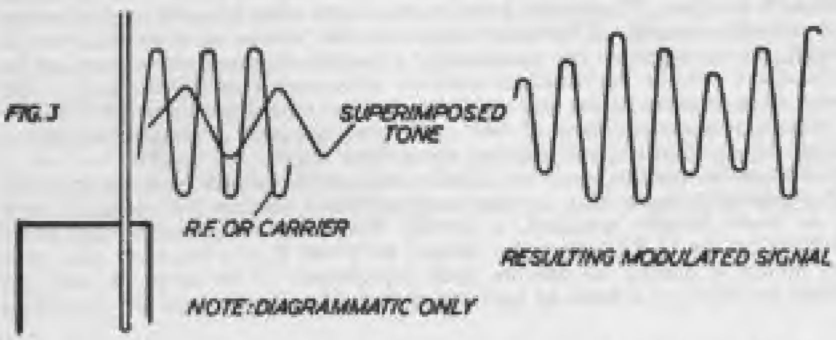
PULSE RATE MAY ALSO BE VARIABLE TO PROVIDE ADDITIONAL CONTROL

to the type of actuator used with it (see Chapter IV) and the system which is built around the actuator(s) (see Chapters VI and VII).

These possibilities—and the limitations which arise—are discussed fully in these later chapters. It is only necessary to recommend here that initial work with radio control models should use the simplest systems. The biggest mistake most beginners make is to attempt too much in the way of control on a first model, and almost inevitably they obtain disappointing results. The cause is not usually failure of equipment so much as failure of the operator to be able to master the use of the equipment, which may involve relatively complicated sequence switching. This is particularly true of aircraft models where response to control movement is usually rapid and equally rapid control switching action is called for. Rudder only, therefore, is a very good starting point.

A lot of disappointment—as well as wasted time and money—can result from the wrong choice of equipment. Even the simplest radio controlled model aircraft is not as easy to fly as it may appear. It needs practice, and plenty of it, to master the art of using the control properly. Expensive equipment and elaborate models, therefore, are not a good starting point because of the human element involved. This, of course, does not apply to boat or vehicle models

FIG. 3



since these are not likely to be badly damaged or written off due to malfunctioning or misapplication of control. A boat model, or a vehicle, minimises the risk to equipment for a beginner, although a model aircraft offers considerably more scope and attraction.

The cost of the simple single-channel equipment available in this country is a little under £10 for a matched transmitter-receiver, to which must be added the cost of a suitable actuator (say from 25s. upwards) and such accessories as batteries, switches and wiring. The total investment—even including the cost of a suitable model (usually built from a kit) plus engine—is thus not unduly high. There is, of course, more expensive radio equipment and actuators and, in the case of multi-channel equipment, the cost may exceed the £100 mark.

Operating costs—neglecting mishaps!—are concerned almost solely with battery replacement. Many of the older type receivers used miniature high voltage high tension batteries which are relatively expensive and have a fairly short life. Modern receivers are more economical on battery requirements, particularly the transistorised receivers. All call for frequent battery replacement, but battery costs are much lower in the lower voltage sizes.

Transmitter batteries, likewise, require fairly frequent replacement, particularly in the case of the smaller physical size batteries used with the hand held transmitters. For reliable radio control operation one must always be

prepared to replace batteries as soon as they show the slightest signs of falling off to dangerously low voltages (see Chapter IX).

Actuator circuit batteries are usually low voltage but subject to quite heavy current drain; hence these too tend to have a relatively short life and need frequent replacement. Most dry batteries, in any case, are heavily over-rated when used for actuator circuits—and often on radio circuits. For this reason re-chargeable accumulator-type batteries are often preferred for actuator batteries (and even for low voltage receiver batteries). Although representing a higher initial cost they may well prove an economy in the long run, as well as giving more reliable service. Converters, powered by accumulator-type batteries, may also be used to provide all the battery requirements for both receivers and transmitters (see Chapter II) and so dispense with the need for battery sets altogether.

A suitable choice of equipment can be gleaned from a study of Chapters II, III and IV, together with the lists of available commercial equipment in the Appendices. In particular, pay especial attention to the choice of actuator. The ultimate success of the control system will depend mainly on the efficiency and reliability of the actuator and, because a particular commercial product is available, it does not automatically follow that (i) it is entirely efficient and reliable or (ii) it is a suitable match to a particular choice of receiver. Your local retailer should be able to assist in the matter of a suitable choice. The same applies to the choice of a suitable model aircraft kit to go with the equipment, although all those recommended in Appendix 6 can be reckoned as suitable with any limitations noted. The choice of a boat kit is far less critical. Radio control gear can be installed in almost any size or type of boat, provided the hull is roomy enough to contain the equipment and support the added weight.

The radio control modeller is also subject to certain legal obligations. His equipment must only be operated within a certain wavelength band, or, as more usually specified, a specific frequency range which has been allocated by the G.P.O. for radio control purposes in this country. He must also obtain a licence to operate such equipment. The latter is obtained merely by filling in a form of application (see Fig. 4) and costs £1 to cover a

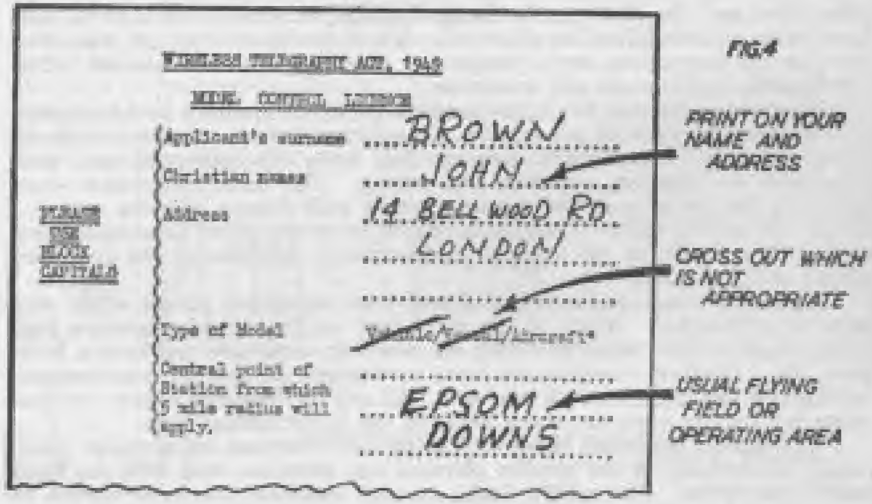


FIG.4

five year period—no examination or technical test has to be passed to obtain the licence, but it is against the law for owners of model radio control equipment to operate such equipment, even for indoor testing, without such a licence. The necessary application form can be obtained from :—

Radio Branch,
Radio and Accommodations Dept.,
G.P.O. Headquarters,
London, E.C.1.

Regarding the permitted frequencies for model radio control operation, these cover the band 26.96 megacycles/second to 27.28 megacycles/second (11.12 to 11.1 metres wave length). The modeller using commercial equipment does not have to bother about this since the equipment as supplied is designed and checked for operation within this band. In some cases the transmitter is tuned to a fixed frequency of signal by incorporating a crystal control (obligatory in the United States but not in this country). It is possible, however, to tune most model radio control equipment which is not crystal controlled outside the permitted frequency range, and this may be done accidentally.

There is another frequency band allocated for model radio control covering 464-465 megacycles/second. This is a very much higher frequency demanding quite a different type of circuit and components and is not used by any commercial equipment currently manufactured in this country. It does offer certain technical advantages, at higher cost, but can be ignored as far as the average modeller is concerned.

Other frequency bands may be available for use in other countries and equipment designed to operate on them. Thus in America some equipment is designed to operate on the 50-54 megacycle band; and in Germany on the 40-41 megacycle band. This again will not normally affect the average modeller since, if imported, such equipment will be set for tuning on the British 27 megacycle band.

CHAPTER II

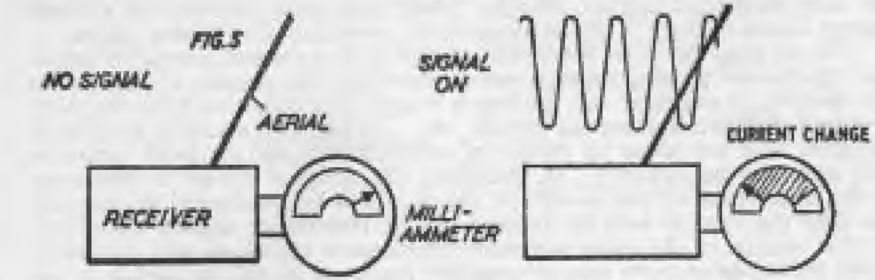
Receivers

WHILE the radio control modeller need not concern himself with the theoretical design of receiver circuits—unless the electronics appeals as an interesting subject—a basic knowledge of the working principles involved is of assistance both in selecting a suitable type of receiver for a particular job and also in adjusting that receiver to achieve optimum performance. The latter requirement is covered by manufacturer's instructions, but these do not explain the differences experienced with different types of receivers, and often merely hint at what may be limitations.

Practically all radio control model receivers are of the superregenerative type. Without going into the technicalities involved, it is sufficient to say that the superregen circuit is ideal for increasing receiver sensitivity in a simple manner, at the expense of making design requirements and adjustment somewhat critical. It also results in a receiver which has fairly broad tuning. By this it is meant that the circuit will tune a fairly broad frequency range so that it will respond not only to the true transmitted frequency from the transmitter, but any stray interference signals near that frequency.

It is thus a highly sensitive receiver in its ready response to signals but tends to lack selectivity or sharp tuning. The circuit designer's aim is to improve selectivity as far as possible, but all straightforward superregen receivers do have this inherent limitation. It makes it difficult, if not impossible, for instance, to operate two such receivers simultaneously and independently in two different models tuned to opposite ends of the permitted frequency band. Although tuned to quite different frequencies, the transmitter signal to one is very likely to be picked up by, and thus influence the operation of, the other. Equally the high sensitivity of superregen circuits makes them susceptible to picking up outside interference. Some superregen receivers, too, can effectively act as transmitters to interfere with the simultaneous operation of another receiver tuned to a slightly different frequency.

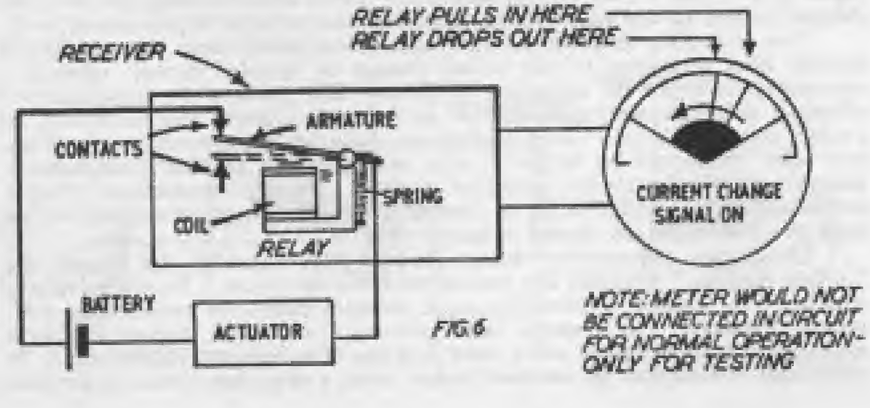
Sensitivity is a much misunderstood property. Sensitivity is obviously desirable to pick up the transmitted signal. The weaker the signal, e.g., the further the distance from the transmitter—the more sensitive the receiver. On the other hand there comes a point where the sensitivity is such that practically any interference effect—even the movement of metallic linkages in the model—will be picked up as a spurious signal, causing erratic response. Thus there is a limit to the sensitivity which can be tolerated; and equally a lower limit of sensitivity necessary for operation at range. The latter is particularly important where transmitter power may be low, as is usual in the case of hand-fed transmitters (see Chapter III).



The simple superregen receiver can be produced as a single valve circuit capable of giving a current change of sufficient value to operate a relay. This latter factor is the basic " switching " operation common to all simple receivers. With the receiver switched on but no transmitter signal (transmitter off), the simple band value receiver will draw a steady idling current (Fig. 5). If the transmitter is then switched on (in practice, by operating the appropriate transmitter signal button or switch), the receiver current will fall to some typical value, assuming that it is correctly tuned. The actual value of low current will depend on the circuit and the valve characteristics.

The difference between the idling current and the current with signal on is quite small—sometimes as low as 1.5 milliamps for example, and seldom more than about 3 to 3.5 milliamps in simple circuits. It is enough to operate an electro-magnetic switch, however, called the relay. The relay incorporates a coil connected in with the receiver circuit (and thus subject to the aforementioned current change), and a pivoted armature which makes with one or other of a pair of separate, independent contacts (see Fig. 6). When the relay coil is energised, the armature is pulled in and makes contact with the lower contact. When current through the relay coil falls to a minimum there is not enough magnetic pull to hold the armature in and so it is pulled out against the other contact by means of a light spring.

The armature and the pair of external contacts form a simple mechanical switch which is used to control (switch on or off) the actuator circuit. Thus the actuator circuit is separate from the receiver and only connected to it through the relay contacts or relay switching action. The relay coil is in the receiver circuit and thus responds to signals from the transmitter causing

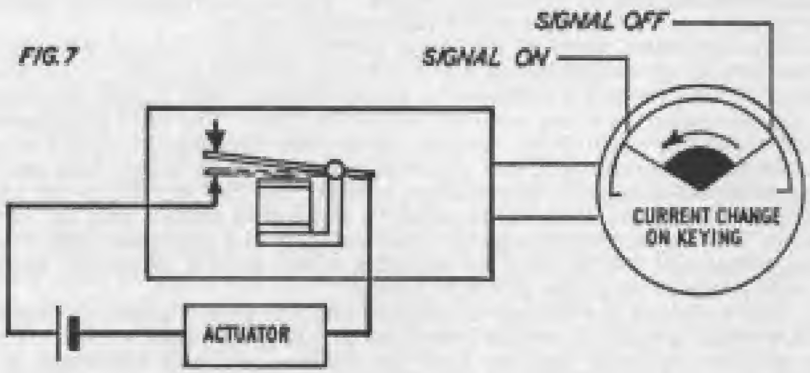


the aforementioned current change. Hence the relay converts the current change characteristics of the receiver into a mechanical switching action.

To do this, the relay is adjusted to pull in at a current somewhat below the top current passing through the receiver (i.e., the current flowing when the receiver is switched on), leaving a margin of current to hold the relay armature in against vibration effects, etc. When this standing current is switched to a low value by receipt of transmitter signal the relay armature will naturally be released. If, therefore, the actuator circuit is connected to the armature and top contact in Fig. 6 it will be incomplete or open all the time the relay is held in (receiver on, no transmitter signal), but closed by the release of the relay armature (transmitter signal on and received). Thus the actuator servo can be switched on or off at will by signals on or off from the transmitter.

Actually this is not the most economic way of working. With no signal the receiver idles drawing maximum current and, since it will normally spend more time idling than actually responding to transmitter signals, this represents maximum current drain. If the system is connected the other way round (which simply means using the other contact on the relay as in Fig. 7)

FIG. 7

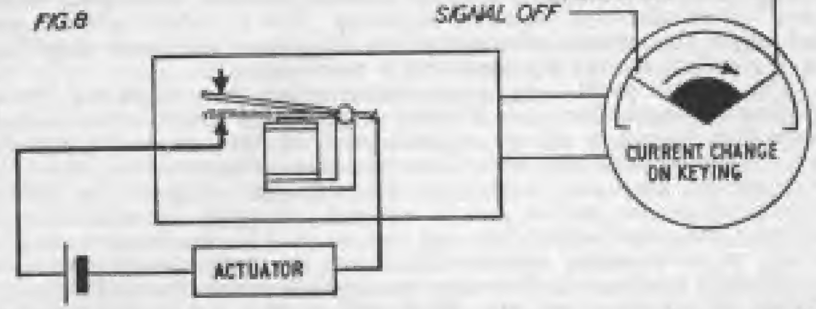


with the transmitter signal normally on all the time, minimum current is drawn by the receiver. To produce a control response the transmitter signal is switched off by the signalling key (or switch), allowing the receiver current to rise all the time the transmitter is held off and so pull the relay in.

The respective methods of operation are referred to as current fall or current rise, according to the actual change of receiver current when the transmitter is keyed for signalling purposes. The latter is the usual method adopted, although not necessarily invariably so. Current rise switching, of course, does result in a more continuous drain on the transmitter batteries but since these can be larger in size and thus less critical than receiver batteries, it is definitely the preferred method. Many modern circuit designs overcome even this limitation by having a normal low idling current which rises to a maximum on receipt of signal—Fig. 8.

The higher the current change (rise or fall), logically, the greater the "safety margin" available for consistent relay operation. Receivers with a small current change require the most sensitive relays for satisfactory, consistent operation. In a single valve receiver the current change is almost entirely dependent on the valve used and the high tension. Hence up to 90 volts high tension may be necessary when using a single hard valve to produce

FIG. 8



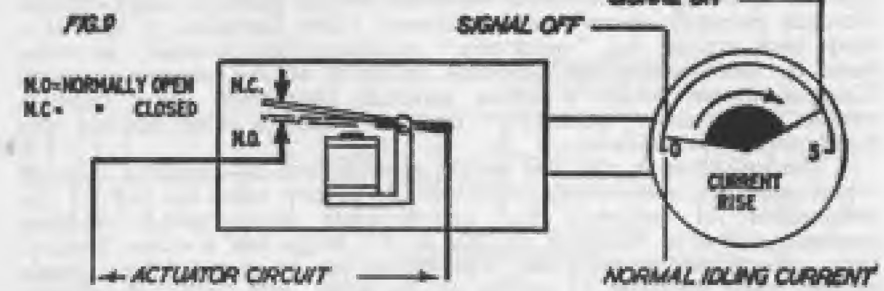
a good current change and give consistent relay operation and good holding in power against vibration, etc.

All receivers operating on very small current changes are suspect as regards relay performance. That is, they require extremely sensitive and efficient relays to give consistent results, with very critical adjustments involved. Most of the early single channel receivers did, in fact, suffer in this respect. Either the relay adjustment was too critical for consistent performance or the "holding in" power of the relay too low for performance under practical conditions. As a result the actuator circuit was not switched positively so that skipping resulted.

A remedy is provided by introducing current amplification in the receiver circuit, although this means more components and thus increases the cost of the receiver. It does, however, have the advantage of making the circuit more stable—the single valve circuit being somewhat of a trick circuit in being called upon to perform several functions, whereas by breaking up the circuit into separate detection and amplification stages each part of the circuit can be made less critical. This is not necessarily the case in all designs, however.

In the case of a two-valve single-channel receiver, a typical arrangement is to use the first valve to bias off the second. The receiver inherently has a low idle current—probably only of the order of 0.1 to 0.3 milliamps—which falls to virtually zero on receipt of signal. This, however, triggers the second valve which now passes a current of anything between 3 and 5 milliamps for as long as the signal is held on—Fig. 9. Thus such a receiver produces current rise of a high enough order to operate a relay efficiently corresponding directly to transmitter signal (i.e. current rises with transmitter signal on and falls to normal (low) idling value with transmitter signal off).

FIG. 9



Two-valve single-channel receivers of this type are generally reliable, although reckoned "old fashioned" by modern standards, particularly where "hard" or vacuum-type values are employed. The so-called "soft" or gas-filled valves (thyratrons) offer theoretical advantages and some simplification of circuitry, but are not consistent in performance.

The modern trend is to use transistors rather than valves for current amplification stages when it is possible to produce a circuit with a current change high enough to operate an actuator direct, thus dispensing with the relay. A further advantage offered by transistors is that they have inherently a low current drain and operate on low voltages. Hence the battery requirements of the receiver can be reduced. Carrying the application of transistors one stage further they can also be used for the detector stage to produce an all-transistor circuit with a very low battery requirement—in the extreme a receiver which requires no relay but produces a current change sufficient to operate an actuator direct with a single 4.5 battery powering both the receiver and actuator.

The all-transistor relayless receiver has virtually become a standard for all new productions, although relay receivers are still produced and have their applications. Only a relay type receiver, for example,

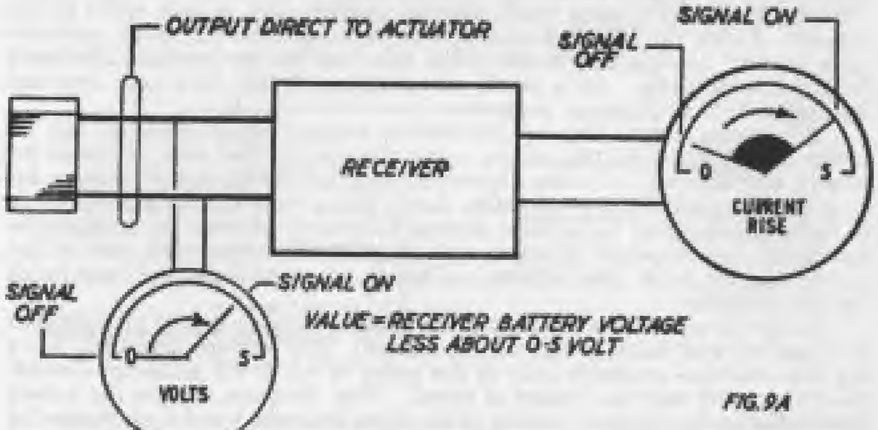


FIG. 9A

provides facilities for "quick-blip" signalling of a secondary actuator (see Chapter IV) since the circuit involved necessitates use of the back contact of the relay. So far, too, relay receivers are the most suitable type for operating single-channel *motorised* servos. Relayless single-channel receivers normally operate an escapement. The limitation of lack of a relay back contact for "quick-blip" switching can, however, be overcome by incorporating the necessary switching on the escapement itself. This, of course, means a special matching escapement for a relayless receiver to provide "quick-blip" facilities. With a relay receiver this facility is always available.

The reduction in size and weight possible with all-transistor circuitry —and also the considerable reduction in battery size—has led to the development of miniature and sub-miniature single-channel receivers (normally relayless) weighing as little as ¾-1 ounce and ½ ounce, respectively. Since both receiver and escapement can be powered by a single battery, itself weighing 1½ ounces at the most, such units are suitable

for installing in the smallest sizes of models. With such equipment the 20-24 span radio controlled model becomes a perfectly practical proposition."

Undoubtedly all-transistor circuitry will eventually replace completely all other types, although some radio designers still prefer to retain a single hard valve for the detector stage, followed by transistor amplification—either with relay or relayless. Without exception miniature and sub-miniature receivers are all-transistor, with the relayless type obviously favoured (for reduced weight and size). The real advantage of the all-transistor receiver is the considerable reduction in battery size (and cost). Performancewise there is probably little to choose between a valve-transistor and all-transistor receiver for single-channel work, provided the transistor circuit design is sound and suitable transistor types are employed. It should be noted, however, that with the relayless single-channel receiver the type of actuator which can be ustd may be restricted—i.e. a particular receiver may only give satisfactory results with a particular type of escapement in order to operate under design (electrical) conditions. The performance of relay receivers is not affected by choice of actuator since the complete electrical circuit for the actuator is quite independent of the radio circuit. The smaller all-transistor relayless receivers may also be susceptible to "interference" from the escapement, although this can usually be overcome by "bonding" (see Chapter VI).

One further limitation of the all-transistor relayless receiver should be mentioned. Both receiver and actuator are operated off the same battery. As a consequence battery drain can be quite high (actuators drawing high currents), and thus battery voltage can fall quite rapidly, particularly when using small batteries. This can result in the receiver ceasing to function after a relatively short period of use.

Usually this can be overcome by employing a DEAC battery of suitable size (capacity) rather than dry batteries. The weight of such batteries is quite low (see Chapter VI) and they are a far better proposition for miniature and sub-miniature receivers than pen cells. One recent commercial receiver overcomes this in a rather different manner by arranging for the relayless receiver to take two separate batteries—one for the "radio" side and the other to boost the "switched" output to the actuator. The receiver will operate as a normal relayless receiver with a single battery, driving an escapement or with the second battery for a boosted actuator supply. The latter set-up has the further advantage of making the receiver virtually independent of any interference from the actuator.

The greater majority of modern receivers of the "tone" type rather than responding merely to carrier wave or continuous wave transmitter signals. The mode of operation remains essentially the same for "tone"

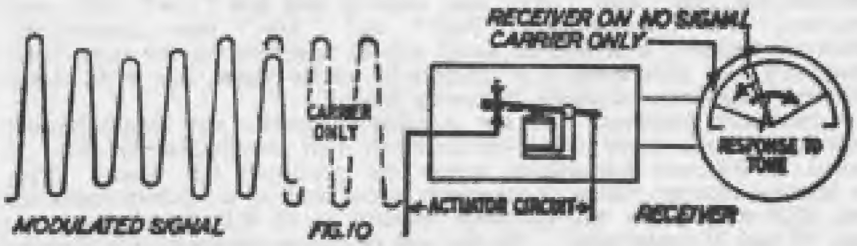


FIG. 10

or "carrier" except that with "tone" equipment the transmitter steady radio frequency (RF) signal is usually switched on all the time and "keying" the transmitter superimposes a lower audio frequency (AF) signal on the "carrier" or continuous signal. Some tone transmitters key carrier and tone simultaneously to economise on battery drain. The receiver circuit is suitably designed to respond to, and produce a current change on receipt of, the AF tone (see Fig. 10)—or in the case of multi-channel rreceivers to distinguish between different tones signalled and activate an appropriate switching circuit or circuits.

Typically, on switching on a tone receiver a somewhat unsteady current drain value is produced of about 20 to 30 per cent. of the maximum current drain. On switching on the transmitter "carrier" the receiver current falls to a steady low value. On receipt of "tone" keyed from the transmitter the receiver current changes to a steady high value.

This may seem an unnecessary complication for single-channel work, if an obvious solution for multi-channel operation. The two terms carrier and continuous are synonomous with the common abbreviation C.W. Carrier wave is used as a description in this country and continuous wave in America. They both mean exactly the same thing—a radio frequency signal transmitted at a fixed frequency. Continuous wave is a rather more realistic description, although with tone modulation the purpose of the main RF signal in carrying the superimposed tone signal is self evident.

A C.W. receiver, for instance, is operating at high sensitivity and stays that way until a signal is received. A tone receiver is receiving a continuous RF signal which tends to desensitize it and make it much less susceptible to outside interference, but readily responsive to AF (tone) modulation. Tone receivers, too, will generally operate efficiently—i.e., at the same range as C.W. receivers—with lower transmitter power and thus are rather more suitable for use with hand-held transmitters.

It does not follow, however, that all tone receivers inherently possess such advantages. Some, particularly those with transistor detector stages (i.e., fully transistorised), are very sensitive and easily suffer from interference (see Chapters IV and IX).

A "tone" receiver will obviously not respond to a "carrier only" transmitter. It has to be used with a matching tone transmitter . The match is usually non critical. Most tone receivers, for example, are designed to respond to an AF signal of between 800 and 1,000 c.p.s. and any make of "tone" transmitter which gives an AF signal of this freqeuncy will work them. It is usual, however, to match a particular tone receiver to its transmitter counterpart. In some cases this is essential for a particular receiver may be designed for a tone response outside the tone range generated by any but a matching transmitter.

It is also possible, if the receiver is selective enough as regards tone, to operate two or even more receivers simultaneously from matching transmitters—e.g. one "high" (AF) tone receiver and one "low" (AF) tone receiver, with corresponding "high" and "low" tone transmitters Both transmitters, it should be noted will be operating on the same radio frequency—i.e. generating a 27 megacycle *carrier* signal, but with widely different superimposed *audio* frequency tones.

Normally, however, it is not possible to operate two single-channel receivers of the usual (super-regenerative) type simultaneously, even if tuned to different frequencies within the permitted RF band. This is because receiver tuning is invariably broad and so a receiver tuned to, say, 27.1 megacycles, will probably respond to all R.F. signals between, say, 26 and 28 megacycles In the case of carrier receivers, it is obvious

that any single(carrier) signal is likely to affect all carrier receivers within its range. In the case of tone receivers, although the response may be to different AF tones, again tone "tuning" is usually quite broad, and response can also be swamped by a spurious carrier signal.

Broadness of tuning, or the liability to pick up spurious signals, can be overcome by employing *superhet* circuitry, but this immediately increases the complication and cost of the receiver. The superhet, however, has the advantage of offering "spot on" tuning so that an individual receiver will only respond to a transmitted signal of the *exact* frequency to which it is adjusted. Thus up to half a dozen (or even more) receivers could be operated simultaneously at different "spot" frequencies within the permitted band without interfering with one another. It should be mentioned, however, that superhets are not necessarily completely free from interference. They can be affected by spurious signals from another transmitter generating a signal at, or including, the "spot" frequency of the superhet.

The main disadvantages of superhets are concerned with the more complicated and expensive circuitry (Fig. 11) and the specialist nature of adjustment and setting up. This expense is normally only justified in the case of multi-channel receivers and so relatively few single-channel superhets have been produced to date. Such sets are supplied ready set up and tuned and require no further adjustment or tuning throughout their life (unless accidentally damaged). In fact, any unskilled attempt to "tune" them after being initially set up will probably result in loss of performance.

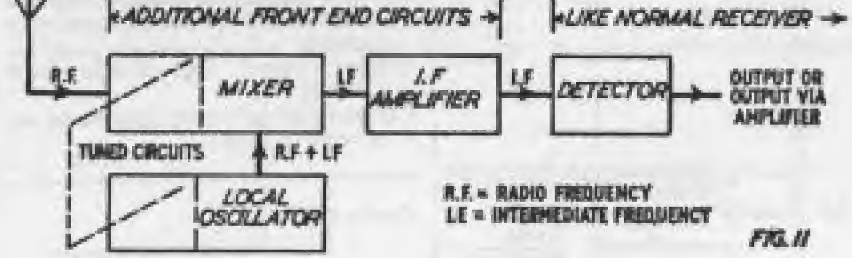


FIG. 11

RECEIVER CHARACTERISTICS

Type	*Operating Signal*	*Characteristics (Response to Transmitter Signal)*
Single Hard Valve	Carrier	Current Fall
Single Soft Valve	Carrier	Current Fall (smaller current change than above)
Two Hard Valves	Carrier	Current Rise (Can also be designed to produce current fall characteristics, but current rise is usual)
Single Hard Valve Plus Transistors	Carrier	Current Rise Capable of giving large current charge)
Tone Receivers (All Types)	Tone	Idling Current (No Signal)—Rather variable about 25-30% maximum current *Carrier* Signal On—Steady Low Current Current rise to steady maximum on receipt of tone
All Transistor	Usually Tone Relayless or with Relay	Current rise
All Transistor Miniature	Tone, Relayless	Current rise
Superhet	Tone	Current Rise—Response to "spot" frequency only

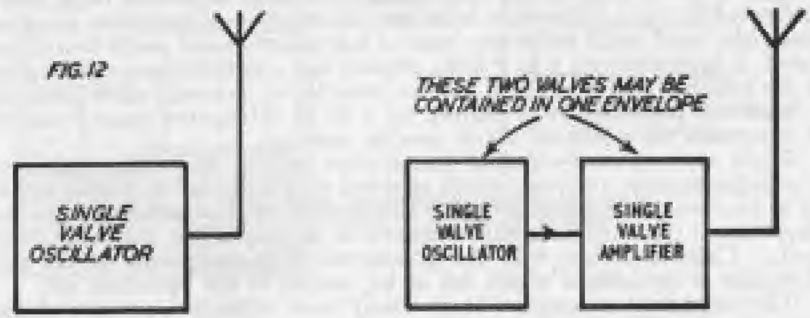
CHAPTER III

Transmitters

TRANSMITTERS for single-channel radio control are either of the C.W. or tone type and can only be used with respective receiver types (although it is possible to modify the switching of a tone transmitter to operate a C.W. receiver by arranging that the transmitter keying switch controls the carrier on and off and eliminates the tone circuit). Any C.W. transmitter should be capable of operating any C.W. receiver (provided it has sufficient power output to realise the required range, consistent with the sensitivity of the receiver). Most tone transmitters will operate most tone receivers (with a similar proviso), but it does not follow that any tone transmitter will be a suitable match for a particular tone receiver. In some cases an abritrary combination may not work at all; in others it may only work inefficiently. For best results, therefore, it is usually necessary to use matched tone transmitter-receiver combinations—either of the same make or at least a transmitter of equivalent type with an optimum tone cycle and degree of modulation.

The simplest type of C.W. transmitter can be based around a single valve oscillator circuit (see Fig. 12) which is the basis of many commercial designs.

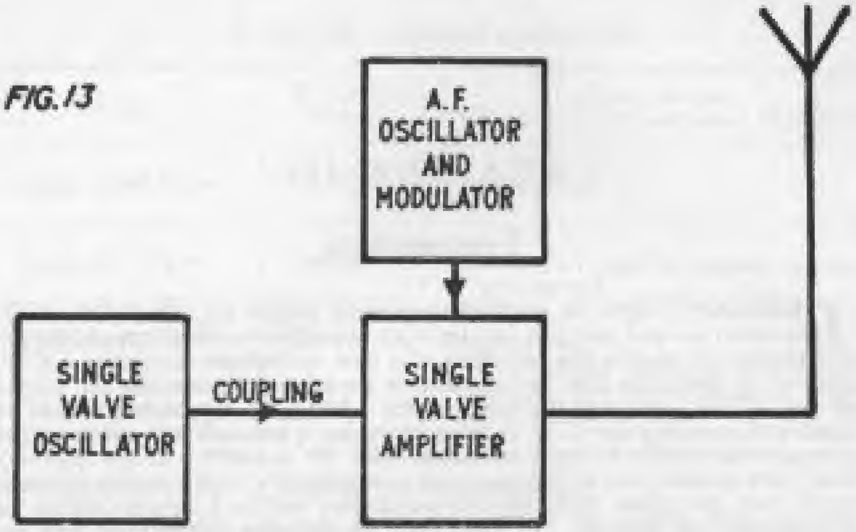
FIG. 12



Such simple circuitry can, however, tend to be extremely critical and lead to inconsistent performance. A two-stage transmitter is generally better, employing an oscillator and an RF amplifier. The two separate valves required may be incorporated in a single envelope so that physically at least, only one valve is apparent. Such two-stage circuits, comprising master oscillator plus power amplifier, are generally referred to as MOPA type.

The MOPA type transmitter is usually preferred for the tone transmitter since it is much more easily modified by the tone applied from a further valve to the RF amplifier stage (see Fig. 13). Actually, again, this would need to be a double valve to produce both AF oscillation and modulation. Tone trans-

FIG. 13



mitters, therefore, contain that much additional circuitry, are two-stage (MOPA) to start with, and thus correspondingly more expensive than the simplest C.W. transmitters. As regards actual physical proportions, however, there need be little or no difference between the two types.

Concerning physical sizes there are basically two types of transmitters—ground-standing and hand-held—the two terms being self-explanatory. Nearly all the early transmitters were ground-standing, employing large, heavy batteries. Particular advantages with ground-standing transmitters are good battery life, good aerial efficiency (since a full quarter-wave aerial length can be used of approxmiately 8 to 9 feet), efficient and consistent ground coupling and the possibility of using high voltage batteries in economic sizes (basically the larger the physical size of battery for a given voltage the more economic it is in terms of ampere-hour life or useable capacity).

While some ground-standing transmitters mount the keying switch on the transmitter case, a keying switch attached to a long lead so that it can be held in the hand and allow movement independent of the transmitter position is more usual (although a possible source of trouble unless properly maintained). Chief limitation with the ground-standing transmitter is the bulk and weight of equipment which has to be carried to the operating site.

The hand-held transmitter is obviously more attractive, particularly for model aircraft work, provided it can be made of a size and weight convenient to hold. Despite the fact that it suffers from serious disadvantages it is now the most popular type for current and new equipment, because of its greater convenience. Nor do its technical limitations appear to have serious consequences for normal use.

Its particular failing is lack of efficiency, compared with a ground standing unit, and the variable factors to which it may be subjected during use—e.g., varying degrees of ground coupling by movement when held in the hand. To get reasonable power outputs, high battery voltages usually have to be employed with relatively small sizes of batteries, resulting in short battery life (and thus high operating costs). This is not helped by the fact that the shorter aerial necessary results in a loss of efficiency; also the telescopic type

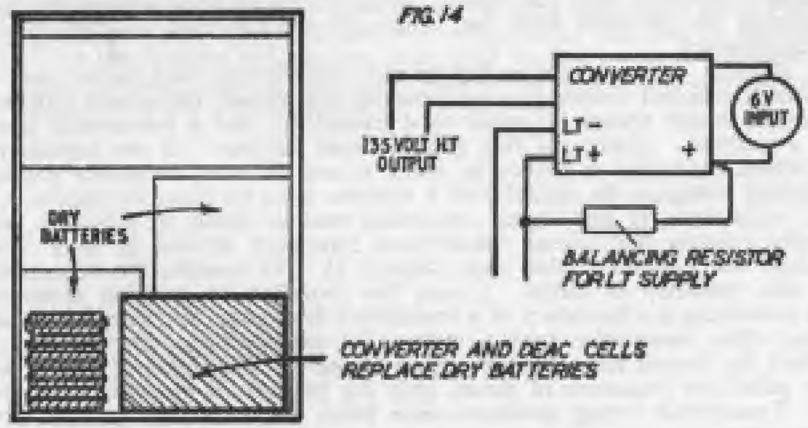
aerial commonly employed on commercial units, because of its attractiveness and convenience, is itself relatively inefficient as an aerial.

The ultimate answer is, of course, the range which can be achieved with a particular transmitter-receiver combination. If this is satisfactory (see Chapter VIII), then the actual efficiency of the transmitter is of relative unimportance. In this respect the tone receiver is usually at a considerable advantage in requiring very much less transmitter power than a C.W. receiver to achieve a similar range—sometimes as little as one tenth of the power, depending on the receiver sensitivity.

Hand-held transmitters, in fact, first became practical for use with the tone receivers, although also developed for and used with C.W. receivers. In the latter case, however, particular attention had to be given in the design to optimum aerial coupling, or a special loading coil employed in the aerial to improve its effective length and radiating power, in order to get satisfactory range.

An attractive alternative to using expensive dry batteries for the transmitter is the converter, powered by a suitable accumulator. In the case of ground-standing transmitters, dynamotor converters or vibrator power supplies may be built into the case, plugging into a suitable 6 or 12 volt accumulator (e.g., a car battery). The development of transistors has made it possible to produce extremely compact and very efficient converters to fit inside standard hand-held transmitter cases, requiring about 6 volts (usually) battery supply (see Fig. 14). Rather than use a lead-acid accumulator DEAC cells or similar

FIG. 14



are normally favoured, as they can readily be housed in the case with the converter unit. The two together take up no more space than the normal high tension and low tension dry batteries and, of course, the converter supplies both these demands.

The all-transistor transmitter is a comparatively recent innovation, due largely to the fact that suitable power transistors were not readily available until the last year or so. Prior to that although an all-transistor transmitter could be made to work as well as a valve transmitter the power output was inevitably lower, with consequently more limited range.

Lack of range (compared with a valve transmitter) is still a feature of many all-transistor transmitters, although this limitation can be overcome to a considerable extent by making the aerial more efficient. Thus

centre-loaded aerials (i.e. a coil in the middle of the aerial) are a common feature with all-transistor transmitters. Several of the later all-transistor transmitters, however, have adequate range on a normal telescopic aerial without using a centre loading coil, particularly when operated with a "matched" receiver.

The great advantage of an all-transistor transmitter is that size and weight can be further reduced—making it even more portable and comfortable for a hand-held unit—and the battery requirements can be reduced to a single 6, 9 or 12 volt battery. Again accumulators are usually preferred to dry batteries as being more reliable and consistent in performance. An accumulator can be charged regularly when its performance can always be relied upon. The condition of a dry battery can only be established by measuring the voltage across the terminals on load (see Chapter IX, Trouble-Shooting Chart). Again the DEAC battery or nickel-cadmium accumulator is usually preferred to lead-acid batteries as being completely sealed units with a long life and high reliability. DEACs take up less space and weigh less than a dry battery (or lead-acid battery) of similar capacity (see Chapter VI).

Basically the average radio modeller must accept the commercial transmitter on trust. Its performance and stability is largely fixed by its design and constructional features. There is little or nothing that can be done to improve performance—other than to ensure that it performs as well as possible by following manufacturer's instructions regarding battery voltages, checking that the battery voltage is maintained during use and replacing the batteries when the minimum recommended on-load voltage is approached.

Tuning will normally be set by the manufacturer and, in the case of crystal controlled transmitters is fixed by the crystal frequency. Thus a receiver should always be tuned to a transmitter, not a transmitter tuned to a receiver. There are two good reasons for this. If the transmitter is crystal controlled it cannot be tuned to any different frequency anyway (without changing the crystal)—so a receiver must be tuned to match. If the transmitter is not crystal controlled and is tuned to match a particular receiver the actual transmitting frequency arrived at may come outside the permitted band (see Chapter I). To operate the transmitter in this condition is illegal. Unless the modeller has suitable apparatus for measuring the frequency of a transmitter frequency, therefore, he should never alter transmitter tuning—unless the manufacturer specifies a procedure for tuning for *maximum signal strength*. This form of tuning will not affect the *frequency* of signal, only the strength of the radiated signal.

Transmitter tuning problems arise when the transmitter is built from a kit. Tuning to match a receiver known to be adjusted (to another transmitter) to a frequency within the permitted band does not necessarily mean that the (new) transmitter so tuned will, in fact, be operating at this same frequency. This is because receiver tuning is so broad. The only thing to do to be on the safe side is to get the transmitter tuning checked by someone who has the necessary equipment to do so. It can then be established that the transmitter is operating within the permitted band.

These comments, of course, apply to transmitters which are hot crystal controlled. All American (and most Continental) transmitters are crystal controlled, but British manufacurers have been slow to adopt crystal control as standard. Mainly this is a matter of cost—the addition of a crystal adding 20/- or so to the price. The greater stability offered and the assured frequency of signal is well worth the extra, however.

The tuning of a transmitter can be affected by mechanical damage, particularly on designs employing unsupported coils. Look inside a typical simple transmitter and you will usually see a large diameter coil wound with a few open turns of fairly thick wire. Any mechanical deformation of this coil can affect the tuning. The better designs provide mechanical support for such coils and the latest technique employing printed circuit construction is to incorporate the coil on the printed circuit itself. In the latter case the transmitter is virtually immune from mechanical damage effects, other than actual damage to the components themselves.

In use the transmitter can be regarded as nothing more than an "on-off" switch (which it is as far as the radio signal is concerned). The only maintenance required is a regular check on the state of the batteries. Certain commonsense rules apply in handling—e.g. do not drop or leave where it can be kicked about—and it should always be operated under suitable conditions. For normal use the aerial should always be fully extended and not in contact with the hand or body. In wet weather protect the unit against rain. This could get inside the case, with resultant harm to components, or reduce the aerial efficiency by running down the base of the arial and "earthing" it to the case.

Virtually all modern transmitters are of the hand-held type, with the emphasis on economic sizes of batteries. In the case of the lighter transmitters, however, small batteries usually mean shorter life, except in all-transistor designs. Commercial transmitters may be either "carrier" or "tone." Some "tone" transmitters also provide for keying the carrier signal only (with tone "off") and so can be used both with carrier and tone receivers. Any carrier transmitter will operate any carrier receiver. Most tone transmitters will operate most tone receivers, but not invariably so. Most efficient working will result only when transmitter and receiver AF tones are of the same frequency.

CHAPTER IV

Actuators, Escapements and Servos

THE terms actuator and servo are used synonomously to describe the electro-mechanical control-movement devices switched by the receiver relay (or operated direct from the current change of a relayless receiver). Basically there are two main types of actuators—those utilising an escapement action and powered by a rubber band (or a clockwork mechanism); and those based around a small electric motor. There is also an intermediate type using escapement-type coils controlling a pivoted magnet, and other variations which can be ignored for the purpose of general description. The term actuator is used to describe all types collectively. For clarity we use the term servo to describe electric motor types and escapements for those types based on an electro-magnetic coil and escapement action.

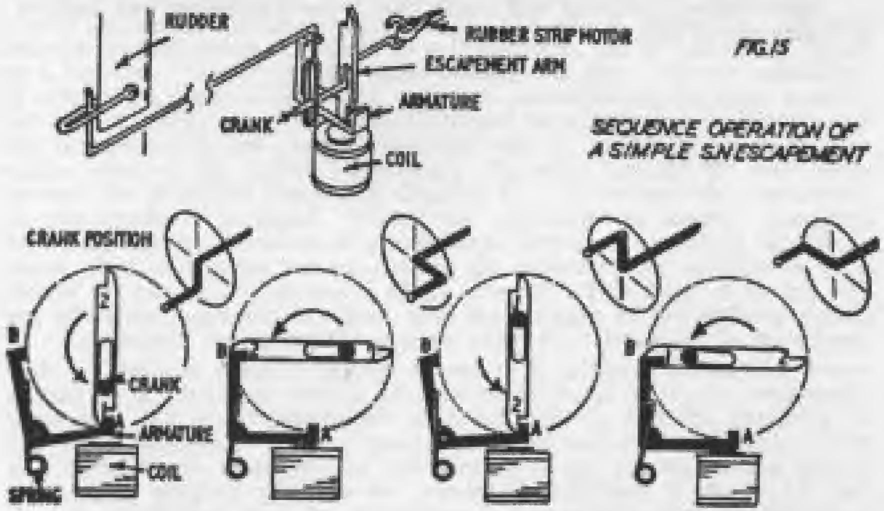


FIG.15

SEQUENCE OPERATION OF A SIMPLE S.N. ESCAPEMENT

A simple type escapement and its action is illustrated in Fig. 15. It will be seen that it consists of a cranked armature pivoted over the top of the pole piece of a coil, the coil and armature movement being similar to that of a relay, as used in a receiver, except that the armature does not operate against electrical contacts. Instead it is arranged to free or stop a pivoted arm, this arm being powered by a light rubber band motor.

The cranked end of the wire on which the arm is mounted (or a pin on the arm itself) engages with a further pivoted linkage. Rotation of the arm through 90 degrees would swing this linkage to one side; rotation through another 90 degrees would bring the arm vertical again and the pivoted linkage back to its original position; rotation through the next 90 degrees would swing the linkage to the other side; and the next 90 degrees of rotation bring it back to the central position once more. This swinging movement of the linkage can be used to move a control surface, e.g., a rudder, the power for such movement being supplied by the rubber motor.

The sequence of movement, as followed by the control surface, would be:

(1) neutral position.
(2) full right (or left).
(3) neutral.
(4) full left (or right).
(5) neutral, and so on.

Now follow this sequence with respect to the escapement action. In the first condition (1) detent A holds the arm against rotation. The coil is not energised. If now the receiver relay operates on receipt of signal to close the actuator coil circuit the armature will pull in and be held in as long as the signal is held. This releases the arm from detent A and allows it to swing through 90 degrees to stop on detent B. This gives position (2). Release of the receiver signal switches off the actuator coil current causing the armature to drop out. Detent B then releases the pivoted arm which now rotates a further quarter-turn to stop against detent A once more—position (3). The next signal releases the arm again and traps it at position (4). Release of signal lets the arm rotate to position (5)—which is the same as (1), the arm having completed one whole revolution.

This has produced a sequence to signal response—

Signal off—neutral.
Signal on—left rudder (or right rudder).
Signal off—rudder returns to neutral.
Signal on—right rudder (or left rudder).
Signal off—rudder to neutral.

The action is self-neutralising—i.e., the control surface always reverts to neutral position on release of signal, with two alternative control positions left or right rudder selected in sequence. Because the response is rapid—movement from neutral to a control position will only take the barest fraction of a second—it is possible to switch through one control position to select the next without the intermediate control position showing any effect.

For example, suppose that the sequence is neutral—left rudder— neutral right rudder—neutral. One press on the transmitter key and held will give left rudder. The next press-and-hold, right rudder. It is therefore necessary to remember which part of the sequence is coming up next. Suppose right rudder is next, but left rudder is required. Keying the transmitter button press-release-press and hold will then quickly engage and release the unwanted right rudder position and stop the escapement on the desired left rudder position.

This is a perfectly practical system for flying a model aircraft on rudder control, although it needs a little practice to master the art of rapid selective switching at will and not lose the sequence. If the sequence is lost, however, it is easy enough to watch the response to a quick signal and then remember that the opposite control movement will be coming up at the next signal. Unfortunately this can often happen and cause delay in getting the model under proper control just when rapid action is most needed; or the

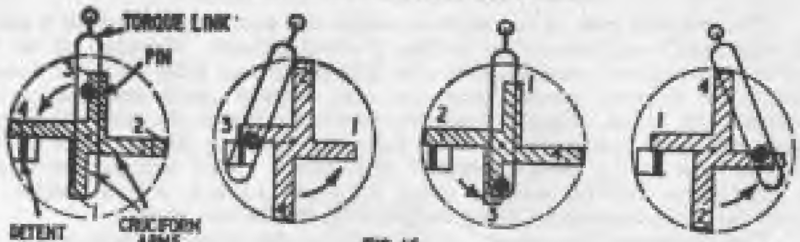


FIG. 16

application of the "wrong" control movement at a particular time be most unfortunate. Nevertheless, the simple two-position self-neutralising (SN) escapement has many virtues and useful applications.

The modern SN escapement usually employs two cruciform arms instead of a single arm (usually in the form of a nylon moulding) when the necessary tripping and locking action can be performed by a single detent—e.g., the end of the armature. The two ends of the "long" arms are engaged when the detent is in the normal position (escapement coil unenergised); and the two ends of the "short" arms when the detent is moved inwards by the armature pulling in. The actual sequence of operation is essentially the same as that of the simple single-arm escapement and can be followed from Fig. 16.

The basic limitation of the SN escapement is overcome in the compound escapement, which can be produced in any one of three basic forms, to provide selective control response. Like the simple SN type it is invariably made self-neutralising so that when released (by release of signal) it reverts to neutral control position (N).

The simplest form provides the same control movements as the simple SN type, but selectively. Its action can be studied from Fig. 17. The arm of the simple SN escapement is replaced by a toothed wheel or cam. The first signal will release the toothed wheel and stop it again on the first tooth position—equivalent to approximately 45 degrees rotation and, say, right rudder. On release, signal off, the wheel then rotates a further 315 degrees to return to its original position. Apply signal again and the action will be repeated—one signal will always give right rudder, returning to neutral on release.

If, however, the signal is given as press-release-press and hold, the first signal pulse will release the wheel, but being switched off straight away will release the armature so that detent B does not stop the wheel on the first tooth. The following press-and-hold signal then pulls the armature in the detent B to stop the second tooth and stop the wheel in the left rudder position. Left rudder, therefore, is always selected by this press-release-press and hold signal. Releasing it returns the control to neutral, as before.

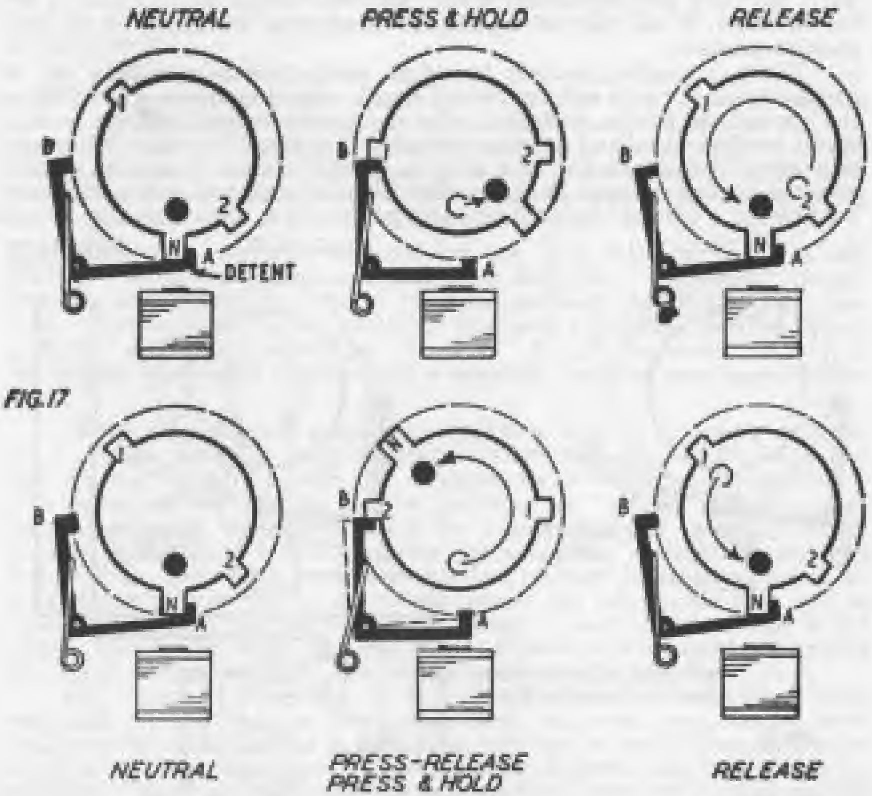
Obviously a certain amount of timing is necessary to achieve the required skip over movement of the armature passing the first tooth. To make this timing "natural," rotation of the toothed wheel is usually deliberately slowed by some form of ratchet brake. Thus the actual time to complete a control movement is somewhat slower than in the case of the simple SN escapement but with very little difference in actual control time, since there is no need to stop and release on the "unwanted" position. It takes only a few minutes practice to become thoroughly familiar with the timing of a compound actuator, so that the required control position is selected positively each time.

Some compound actuators also incorporate a third stop, and thus a further control service. In this case the position of the third tooth is made very near to neutral control position of the toothed wheel so that when this position is held the main control linkage connected to rudder is not appreciably displaced (see Fig. 18). Since this further selective position does not give any independent mechanical movement it is used simply to close a pair of contacts which can connect to a further actuator and thus provide switching for this second actuator circuit on or off. It can, however, be used to provide mechanical movement by cascading (see Chapter VI).

To select the third control position the signal required is press-release-press-release-press and hold. The third tooth is then stopped by the detent B and the cam on the toothed wheel now stops against the contact spring and holds the contacts closed. This closes the second or auxiliary actuator circuit to bring it into operation, e.g. to operate a motor speed control.

Note that there are two ways in which this third position set of contacts may be used as a control switch. If they are used quite independently as a switch the circuit will be made momentarily every time the third control position is passed by the toothed wheel returning to neutral from either of the other two signal positions. This might be acceptable using a motor servo but could accidentally trip an escapement. The usual method, there-

FIG. 17



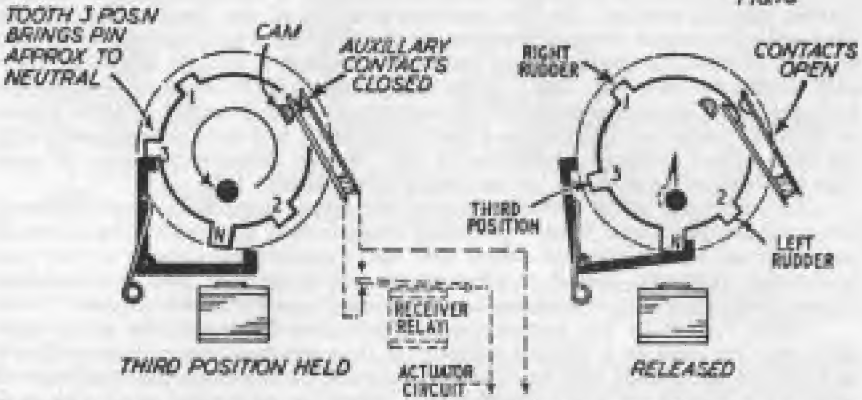


FIG.18

fore, is to connect the third position contacts in series with the relay receiver contacts. When the third position is held both sets of contacts are made, completing the circuit. When the third position contacts are only momentarily made as the escapement rotates to neutral the relay contacts are open. Thus the third position circuit is not completed under such conditions and hence there is no risk of tripping an escapement controlled by the third position contacts.

There is another method by which third position switching can be obtained with a much simpler control signal—this time a very quick blip on the transmitter button, sufficient only to trip the neutral holding position on the toothed wheel and subsequently allow it to rotate through a full revolution before being brought to a stop in neutral again. A cam or suitable projection is incorporated on the toothed wheel to wipe over and momentarily hold closed a pair of electrical contacts positioned as shown on Fig. 19 and

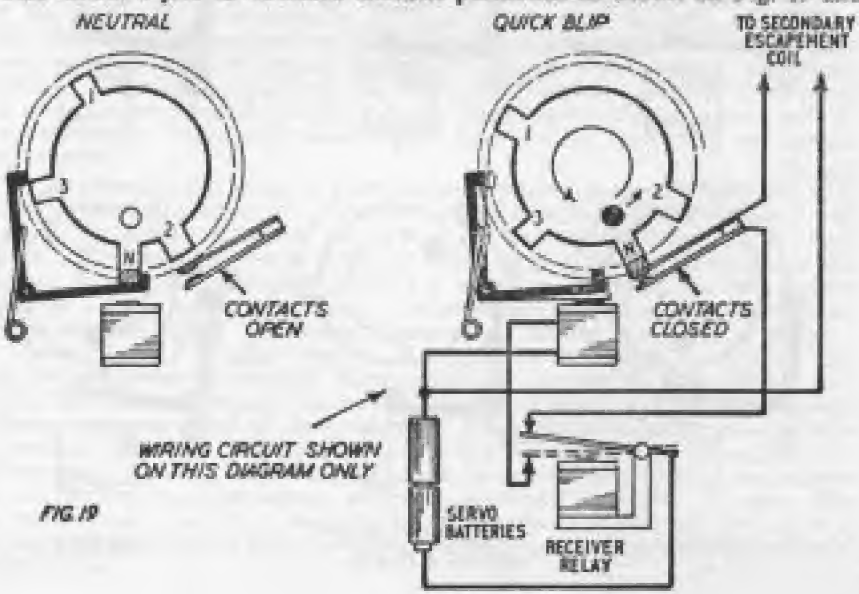


FIG.19

wired to the back or normally unused relay contact (in the receiver) as well as the secondary actuator coil.

The receiver relay in this case governs whether the secondary actuator circuit will remain open or can be closed by the contacts on the compound escapement. If the receiver relay is pulled in the secondary circuit will remain broken at the back relay point, irrespective of whether the secondary contacts on the compound escapement are made or not by passage of the cam. If the receiver relay is just triggered, however, to release the toothed wheel, the armature will revert to the normally open position before the secondary contacts are closed by the advancing cam. Thus when this cam closes the secondary contacts the secondary circuit is completed, bringing that actuator into operation.

Quick-blip selective switching of this type may be combined with third position selective switching on the same compound actuator, thus giving two selective control positions with mechanical operation; and two further independent electrical switching points for two more auxiliary services operated via separate actuators. There is, however, a subtle difference between these two selective switching positions. In the case of the hold switching position (third tooth) the circuit can be held closed for as long as required and is thus suitable for operating a motor-driven servo or an escapement. In the case of the quick-blip switching position, the contacts are only held closed for a relatively short period by the passage of the appropriate cam. This position cannot be held and so these contacts are only suitable for triggering an escapement.

It should be noted also that, in practice, the electrical contact switches may not be separate leaf-type contact arms operated by a cam, but take the form of a printed circuit etched on the base panel of the compound actuator and swept over by electrical wipe contacts, although the principle of operation remains the same. This type of switching gives several advantages, both in construction and operation, particularly as regards control of timing of the contacts.

Escapements specially designed for use with relayless receivers and provide "quick-blip" response incorporate both the "quick-blip" closure contacts and a separate pair of contacts replacing the usual relay contacts. Without such special switching provision a relayless receiver cannot provide "quick-blip" switching response. It will, however, provide all the normal mechanical responses of a standard single or compound escapement.

The design electrical output of a relayless receiver is usually matched to a specific electrical load, normally specified in terms of escapement coil resistance—e.g. "suitable for escapements of 8 ohms coil resistance." The actual voltage switched will be less than the "single" battery voltage used—how much less depending on the efficiency of the switching circuit. A drop of 0.5 volts is fairly average for a receiver designed to work on 3-4.5 volts. Thus with a 4.5 volt relayless receiver designed to match an 8 ohm escapement the actual voltage across the escapement coil will be about 4 volts and the corresponding current = volts/ohms = 4/8 = 0.5 amp. This would imply that the output transistors are capable of passing 0.5 amps without damage, but probably not very much more.

For satisfactory working it is essential that the escapement work efficiently on the voltage available. Most American escapements work satisfactorily on a nominal 3 volts, and continue to work down to 2 volts or less. British escapements are normally designed for higher voltage working. Thus an American relayless receiver may not provide enough

voltage output to operate a typical "4.5 volt" escapement, only one specified as a "3 volt" type.

A few calculations will usually show what the position is. Suppose the relayless receiver is of the 3-3.6 volt type for an 8 ohm escapement, and assuming that the full 3.6 volt battery supply is used. Escapement voltage available will be about $3.6 - 0.5 = 3.1$ volts, say 3 volts. Current = volts/ohms $= 3/8 = .375$ amp.

A typical 4.5 volt escapement may have a coil resistance of 8, 10 or even 12 ohms. The typical design current in each case will then be:

8 ohm coil, current = 4.5/8 = .5125 amp
10 ohm coil, current = 4.5/10 = .45 amp
12 ohm coil, current = 4.5/02 = .375 amp

These current figures are significant since the effective "pull" of the escapement coil is determined by the number of ampere-turns. The number of turns in the coil being fixed, any variation in current will therefore affect the "pull" and thus the working of the escapement.

Check the current values available with a 3 volt supply to the escapement.

8 ohm coil, current = 3/8 = .375 amp
10 ohm coil, current = 3/10 = .3 amp.
12 ohm coil, current = 3/12 = .25 amp

In each case the current and thus the ampere-turns, will be down by one-third.

Suppose we compensate for this by increasing the receiver voltage to 4.5 volts. Output switched by the transistors will then be about 4 volts and currents nearly back to those required.

8 ohm coil, current = 4/8 = .5 amp
10 ohm coil, current = 4/10 = .4 amp
12 ohm coil, current = 4/12 = .33 amp

Note, however, that in this case the current for the 8 ohm coil is well above the design value for the transistors switching the output (.375 amp) and quite possibly the transistors would be incapable of switching the full .5 amp even on 4.5 volts, without risk of burning out. Both the 10 and 12 ohm coil escapements could, however, be handled and would probably be suitable on 4.5 volts receiver battery.

Still further possibilities are available with compound escapements by combining or cascading two or more compounds and suitable grouping of the switching circuits. It is theoretically possible to provide an almost infinite number of separate controls in this manner. In practice, however, cascaded systems tend to become unworkable with more than four selective hold positions due to the delays involved. The use of cascaded escapements in any but elementary hook-ups (see Chapter VI) is, in any case, beyond the scope of this present book.

Escapements are the logical choice for single-channel work and the best type of actuator, in any case, where the most rapid control movement response is required. The output force which can be delivered by an escapement, however, is strictly limited to the maximum size of rubber motor the escapement can accommodate without binding. Usually this motor consists of two strands of 1/8th or 3/16th strip, and never more than two strands of 1/4 strip (and then only when the escapement is specified as, or proves capable of, accommodating such a rubber motor). To a large extent the rubber size is governed by the voltage applied to the escapement and some are specified for different voltage operation—e.g., 1/8 in. rubber on 3 volts, 3/16 in. rubber on 4.5 volts, 1/4 in. rubber on 6 volts.

Escapements are almost invariably employed with relayless receivers

to date, due largely to the fact that suitable motorised servos matched to relayless receiver (electrical) outputs have not yet appeared as standard productions—a position which will shortly be remedied. There is also the fact that a motorised actuator is very likely to interfere with the working of a relayless receiver when directly coupled to the circuit. One way of getting round this by "splitting" the circuit is mentioned in Chapter II.

Where more power is required to operate a control surface—e.g., a marine rudder (but see also Chapter VI)—a servo unit may be called for. Basically this consists of a small electric motor of suitable type and performance, usually driving through gears, and controlled by a suitable switching circuit to respond, as required, to the available switching from the receiver.

Motor-driven servos are most widely used with multi-channel operation and normally require two channels for operation. However, there are motor servos specially made to suit single-channel operation, either directly or by modified signal switching; and a number are also adaptable to different modes of operation by changing a printed circuit switching disc.

Logically, servos should be classified in the same way as escapements, but this is not done, nor is their application always obvious. Basically, they can be grouped as single channel or multi-channel types. Single-channel servos can be produced to give sequence switching, as with the simple SN escapement or selective switching in the compound escapement (and with a third position available, if desired), and self-neutralising in both cases. The same servos may also be made to operate progressively (with no self-neutralising action), either by a change of wiring or change of contact disc. Further compounding variations may also be available with additional contact discs. It is therefore important to ensure that the correct type is selected for a particular purpose. Progressive servos, with single-channel operation, are virtually limited to model boat application (see Chapter VII).

Other types of proportional servos, which may be specified as suitable for single-channel operation, depend on the use of a pulse box or similar device to modify the transmitter signal. These are not normally suitable for simple single-channel operation.

Multi-servos are designed specifically for multi-channel use and are normally intended for operation via two separate signalling channels. They can be connected for self-neutralising or progressive action, as required (or alternative servos supplied with different switching arrangements). No multi-servo is directly applicable to single-channel operation since it must be controlled by two separate switching actions. However, a conventional escapement operated directly by a single-channel receiver can readily be modified to operate the necessary switching to control a multi-servo, either progressively or with self-neutralising action—see Chapters VI and VII and Figs. 35 and 38.

Also a progressive action "multi" servo can be used with single-channel radio adapted for "pulsing." In this case the transmitter signal is broken into a series of pulses of on-off signals, variable receiver response being produced by varying the ratio of "on" to "off" in the signal. Description of "pulsed" systems is, however, outside the scope of this present book on simple single-channel radio.

A majority of early servos were poor both in design and construction. The position is now considerably improved and the best are thoroughly reliable for the duties they are intended to perform. With single-channel systems, however, they are mainly employed for model boat and vehicle control movements, or for secondary control operation on aircraft models. With more complex aircraft control systems motor-driven servos almost invariably replace escapements.

CHAPTER V

Aircraft Types and Engines

IN the early days of radio control, flying models were large and heavy, mainly because the receiver-actuator gear complete with batteries was also somewhat bulky and heavy. A complete single-channel system weighed around 16 ozs. Today, receivers are much more compact and very much lighter. A single-channel installation is a perfectly practical proposition in a 30 inch span model, or even smaller. Equally, it could be fitted in a 6 ft. or 7 ft. span model.

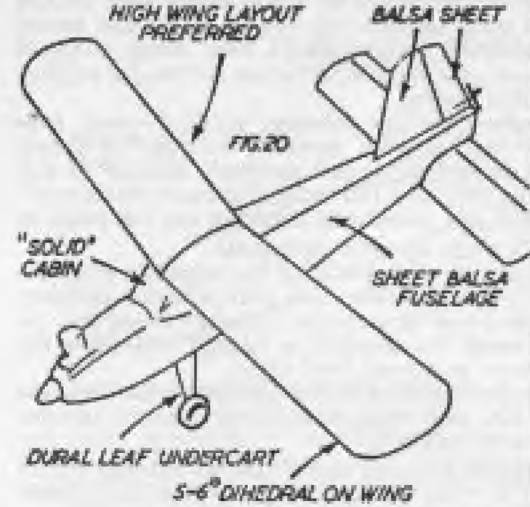
Very small models, however, are not all that satisfactory. They are rather more tricky to control, far more sensitive to gusts of wind and often tend to be underpowered. If the latter fault is overcome by fitting a large engine, the faster flying speed and heavier loading again tends to make the model even more tricky to trim and handle.

The introduction of miniature and sub-miniature receivers of the relayless all-transistor type (see Chapter II) has, however, considerably increased the scope popularity of the small radio model. The complete radio gear—embracing receiver, battery and escapement—can work out at less than 3 ounces, a payload that can be handled by the smallest practical sizes of power models. These can range from 18-22 inches span powered by .01 glow motors, up to 30-34 inches span powered by .049 glow motors. Rudder-only control is used on the smaller models but a compound escapement with a "trip" action for elevator trim is perfectly practical on models of about 30 inches span, adding no more than half an ounce of extra weight.

A point here is that although the receiver can be miniaturised to a degree the escapement cannot. Matching "miniature" escapements have been produced to go with the very small receivers, but are not much smaller in weight or bulk than standard escapements. This is because the orthodox design of escapement cannot be scaled down without drastic loss of efficiency and increased production difficulties.

Whilst small radio controlled models have a definite attraction—and represent extreme economy in money and time in building—they are essentially for calm weather flying only. They must be built light for satisfactory performance, which means that in winds they will merely be "radio affected" rather than "radio controlled."

The very large model is also at a disadvantage with single-channel control, besides being more expensive to build and difficult to transport. A wing span of 4 ft. to 5 ft. is generally reckoned as about the ideal size for single-channel work, which may be powered by engines ranging from 1.5 c.c. to 3.5 c.c., depending on the design. Many suitable designs have been published in this size range and a considerable number of kits are available. The great advan-



PRACTICAL CONTROL SCHEMES SIMPLE SINGLE-CHANNEL	
CONTROLS	ACTUATOR
RUDDER ONLY	S.N. ESCAPEMENT OR S.N.COMPOUND ESC'M'NT
RUDDER HIGH-LOW MOTOR	COMPOUND ESC'MENT. PLUS SIMPLE S.N ESC'MENT.
RUDDER MOTOR 'KICK' ELEVATOR	DOUBLE CASCADED COMPOUND ESC'M'NTS PLUS SIMPLE S.N ESC'MENT. FOR MOTOR SPEED

tage in building from a kit, or to a standard design, is that the qualities of the design have been proven and thus the model is known to be suitable for radio control work. It does not follow that any free flight sports model will be suitable for radio control, for many of the design requirements are different.

Classification of radio control models by type is largely arbitrary in this country. Broadly speaking, however, designs fall into one of five main categories (see also Fig. 20).

(i) Models designed for rudder-only control (although this is often associated with a second control, e.g. motor speed, using a compound actuator). These almost invariably use single-channel equipment.

(ii) Models designed for multi-control systems and employing, typically, rudder, elevator and motor control, to which may be added aileron control, elevator trim, steering and wheel brakes, depending on the number of channels available. These invariably use multi-channel equipment.

(iii) Intermediate class designs which may incorporate any number of different controls or combinations of controls but worked via single channel equipment. A model with rudder control and one or more extra controls given by a compound actuator may be classified as Intermediate for contest work.

(iv) Race type planes designed specifically for flying a course—designated pylon class in America. These may be either single or multi but are usually multi-channel.

(v) Flying scale models. With the development of highly reliable multi-channel control systems the radio controlled flying scale model has become a perfectly practical proposition for the experienced modeller and radio flyer. Scope is very much more limited with single-channel equipment, however.

The main differences as far as design is concerned is that models of type (i) normally have a considerable reserve of inherent stability, like a free flight model, so that with neutral control they recover to a normal flying attitude. Some designs, in fact, may look very much like sports free flight models and may be developed directly from them. However, to achieve smoother, faster

flying, models of this type designed specifically for radio control work usually have reduced dihedral, different wing sections and rigging angles and beefed up construction. Most are high-wing designs with a solid cabin, although there are exceptions. In the main, the high wing layout is best for rudder-only control, particularly for a first model.

Multi-channel designs usually have less inherent stability—some have virtually no automatic stability—and are not generally suitable for simple single-channel operation. The highly developed aerobatic designs of this type, notably the low wing layouts, rely on a full range of controls being available to fly them successfully. It is not possible to duplicate the full range of selective controls necessary with single channel equipment.

The true intermediate design aims at duplicating the aerobatic possibilities of the multi-channel design but at the same time incorporates a sufficient reserve of stability so that in the event of a control sequence being lost (or misapplication of control), returning the controls to neutral will allow the model to sort itself out and recover in normal level flight.

Racer or pylon type designs are relatively new to this country. They are an interesting type to fly for fun with single-channel equipment, but for contest work multi-channel is really required.

The possible range of prototypes for scale model aircraft virtually covers classes (i), (ii) and (iii) above. That is to say the scale prototypes which make satisfactory free flight models with a good reserve of inherent stability are suited to single-channel rudder-only control. Those with little free-flight stability (the low-wingers again) are suited only for multi-channel controls. Between the two there are a number of designs which have reduced inherent free flight stability but could make successful radio controlled models either with some additional controls available or with the layout slightly modified to improve stability.

There is another class of single-channel design which we have not considered—those based around the single-channel proportional control systems. These, even more so than the "multi" design, rely mainly on full control being maintained by the "pilot" all the time. They do not, therefore, make suitable designs for simple single-channel systems.

Now a word on engines. Diesels are the most favoured type of engine in this country; glow motors in America. In medium (1-2.5 c.c. sizes), the diesel often develops more power than its glow counterpart. It is also heavier. This means that replacing, say, a 2.5 c.c. glow motor, as specified for a particular American design, with a 2.5 c.c. diesel, the balance of the original design may be upset by the heavier motor; also the model may be overpowered by the original standard.

The difference in weight can usually be neglected. Extra weight forward is usually a good thing because the natural tendency is for all model aircraft to work out tail heavy. A forward centre of gravity or balance position is definitely best for radio work (25 to 33 per cent. chord). If necessary the heavier components (e.g., batteries) can be positioned to arrive at the final balance required but modern transistor equipment, with small batteries, is so light in weight that often ballast is necessary in the nose to arrive at a final balance in the right place. A slightly heavier engine should therefore present no worries.

Any extra power available can also be beneficial, unless there is some fault in the design. To achieve a good aerobatic performance—and this is readily possible on a good design even with rudder-only control—plenty of power is required, always provided this is not excessive to the point of reducing the inherent stability of the model and making it tricky to handle.

For all its virtues in this respect the diesel does, however, have one basic

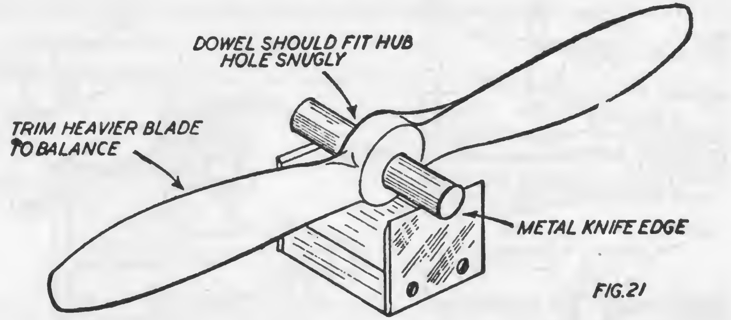


FIG. 21

disadvantage compared with the glow motor. It tends to vibrate much more and mechanical vibration is something which can seriously interfere with the radio operation by causing sympathetic vibration of the relay—to say nothing of imposing extra strain on hinges, soldered joints, etc., and even cause control rods to bind or actuators to fall apart.

Engine vibration is something one is more or less forced to accept. Some engines vibrate more than others. Most engines have speeds at which there is maximum vibration. With a given engine it is important to choose a propeller size which allows it to run at speeds which avoid excessive vibration (remembering that the propeller will speed up quite a bit when in the air).

Excessive vibration is also caused by an unbalanced propeller. Few, if any, commercial propellers are perfectly balanced, even the moulded plastic types. Since these are almost invariably preferred for radio work, and are heavier than wooden types, unbalance effects can be quite marked. If an engine does vibrate badly on a particular propeller, loosening the propeller and retightening it in position after turning through 180 degrees will often show a marked improvement. In most cases a best propeller position can be found which gives minimum vibration when running, although this is not always a convenient position for starting.

It is a relatively simple matter to balance a propeller by mounting on a dowel rod which fits the hub hole fairly tightly and then balancing on a couple of knife edges (see Fig. 21). Material is then pared or filed off the heavier blade until the propeller rests in a level and balanced position. A perfectly balanced propeller will not cure engine vibration, however. A single cylinder engine is inherently unbalanced and it may still be necessary to find a best propeller position.

Many of the popular sizes of engines suitable for radio control work are available with throttle controls (see Fig. 22). Practical methods available for controlling the speed of motors include:—

(i) Twin spraybars and needles—one giving a normal mixture for high speed running and one a very rich mixture for low speed running. The engine speed control then switches the main fuel feed from one spraybar to the other. This system has been largely superseded by other types although it is still used and gives good results on many engines (diesel and glow).

(ii) Barrel-type throttle control. This gives the same effect as above, enriching the mixture to produce slow running. It can be operated by a simple push-pull movement.

(iii) Exhaust flap. This embodies a pivoted flap which can be rotated

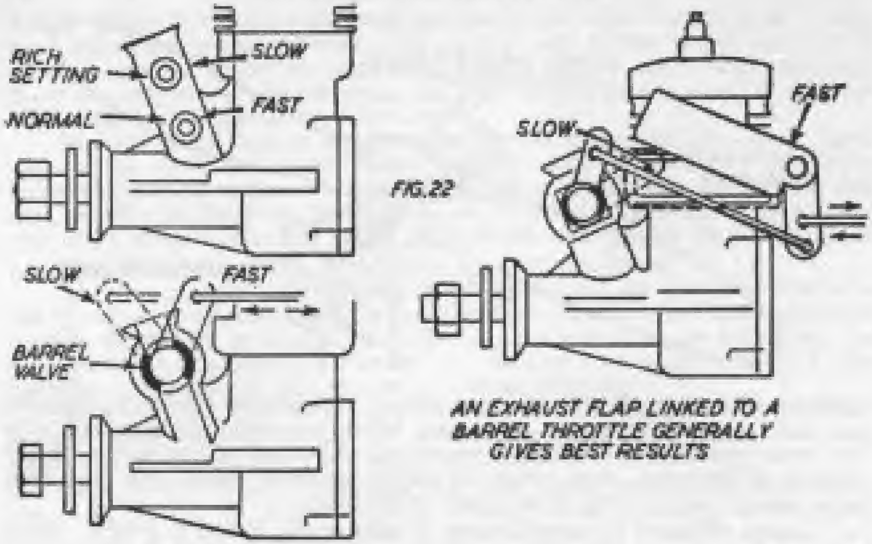


FIG. 22

AN EXHAUST FLAP LINKED TO A BARREL THROTTLE GENERALLY GIVES BEST RESULTS

to almost completely cover the exhaust (and is thus virtually limited in application to engines with an integral stub exhaust, or that can be fitted with a suitable exhaust stack). It produces slow running by back pressure effect while retaining a very lean mixture. It works on both diesels and glow motors.

(iv) A combination of barrel-type throttle and exhaust flap, connected by simple linkage. This is the best form of motor speed control for glow motors.

With simple single-channel systems it is readily possible to operate a throttle control off the third position of a compound escapement, or off the quick-blip switching action if a more rapid selection is required.

Manoeuvre	Action	Remarks
Level Turn	Blip rudder on and off	Type of turn will depend on model design and trim—e.g. a large dihedral angle will make the model wallow in a blipped turn; an underelevated trim will tend to make the nose drop (blip on must be spaced out accordingly).
Climbing Turn	Occasional blip on rudder.	Fairly wide turns only possible with model normally trimmed for straight flight.

Manoeuvre	Action	Remarks
Gliding Turn	Rudder on and off, as necessary.	Employ blip technique for smoothest turn. Rudder action is now less powerful, however, so rudder positions can be held on for slightly longer periods.
Loop	(i) Climb to 500 ft. (ii) Hold on left or right rudder to make two to three turns of a spiral dive. (iii) Neutralise rudder to straighten out model heading directly into wind. (iv) Excess airspeed built up in dive should now take model over in a loop.	The ability to perform loops with rudder-only control depends on the trim of the model. A model trimmed underelevated may not be able to complete a loop but will stall, turn or roll off the top.
Consecutive Loops	As for loop but build up more speed in dive by at least three turns of a spiral dive.	Depends on trim of model. Some models will not perform more than one loop however much speed is built up on the dive.
Spiral Dive	Hold on rudder (left or right).	Never attempt this manoeuvre from low altitudes (e.g. never less than 500 feet).
Spin	Not possible.	A true spin is not possible with rudder-only control.
Roll	(i) Climb to 500 ft. minimum. (ii) make three turns of a spiral dive. (iii) Neutralise rudder to bring model out heading crosswind. (iv) blip on left rudder, then hold on right rudder.	The character of the roll, and the ability to roll, depends very much on the design and trim of the model. It normally needs a fast flying model to perform this manoeuvre successfully.

Manoeuvre	Action	Remarks
Lose Height	(a) perform spiral dive.	Use only for losing height from a considerable altitude. Model will lose ground downwind with this manoeuvre.
	(b) Throttle engine	Model can then be steered back in a glide approach.
	(c) Blip on *alternate* rudder (right and left).	This causes the model to weave and dive — a most effective method of control once mastered. It can be done with full-speed engine or low-speed engine.
Improve Penetration	(a) trim adjustment.	Increase positive rigging of tail-plane to underelevate model in windy weather (*Note:* this may affect the model's ability to perform certain manoeuvres).
	(b) Blip on alternate rudder (as (c) above).	This is done with full-speed engine. Take care not to lose the model in a complete 180 degree turn.

CHAPTER VI

Aircraft Systems

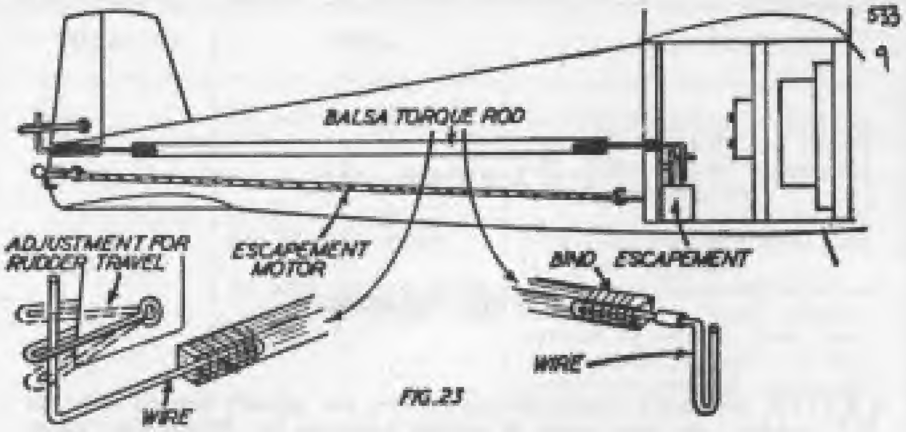
WITH all simple single-channel systems the primary control must be rudder. An escapement is entirely adequate for driving the rudder (either SN or compound), even on the largest size of model. If the model is fast flying, or the rudder area relatively large, the rudder can be aero-dynamically balanced to relieve the escapement of excessive load and ensure positive operation of the rudder control under the power available from the escapement rubber motor. A motor-driven servo is not usually successful for single-channel rudder-only control because of the greater time lag between signal on and the completion of movement of the rudder to the right or left rudder position. For complete control, and maximum manœuvrability using rudder-only, virtually instantaneous control movement is required. Whatever form of actuator is used it must also be self-neutralising.

The scope, even with rudder-only control, is considerable. Basically the rudder provides only a turn control, usually very powerful in effect and so must only be applied in moderation—i.e., for short periods. If a rudder control position is held on, the turn initiated will rapidly develop into a spiral dive. Hence a flat turn with minimum loss of height is accomplished by blipping on the appropriate rudder signal. In effect, the model is made to complete a turn through a series of partial turns and intermediate recoveries. The result may be a fairly smooth turn or a jerky turn with the model rolling from side to side—depending on the aerodynamic characteristics of the model and the manner in which the control is blipped. Technique, as regards the latter, has to be matched with the behaviour of the model.

Various other manœuvres can be performed with rudder-only, although for some it may be necessary to re-trim the model. Typical manœuvres possible and the method of accomplishing them are summarised in the Table in Chapter V.

The chief limitation with rudder-only control is apparent lack of ability to control climbing effects. Models coming out of a turn, for example, will naturally tend to zoom. Likewise, a model headed into wind to keep it from losing ground downwind will normally tend to climb strongly and lack penetration. Lack of penetratian and zoom effects can be offset to some extent by trimming the model slightly underelevated (compared with normal free flight trim). There is a limit to which this can be carried, however. If the under-elevation is too drastic the model may tend to dive and lose a lot of height on every turn and may even tuck under and dive straight in if the nose drops following a manœuvre.

Rudder can, however, be used to impart a down elevator effect by blipping on alternate rudder signals. This will produce a weaving motion, resulting



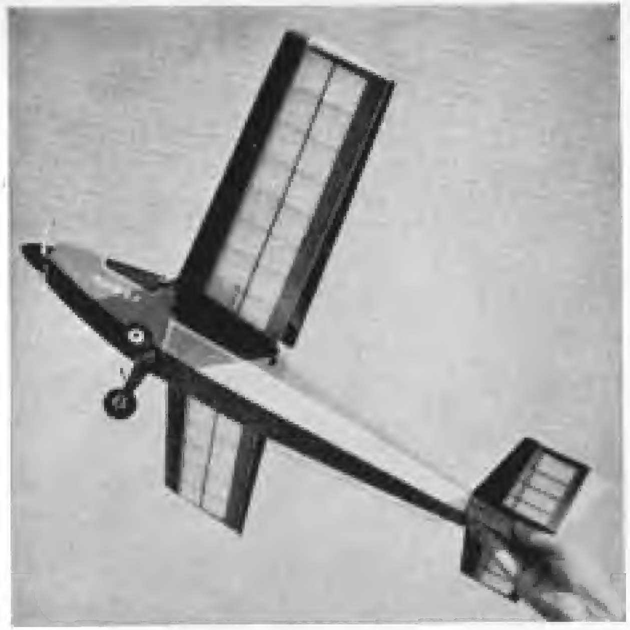
from the start of a turn, recovery, start of a turn in the opposite direction, recovery, and so on. The weave will be accompanied by loss of height. Such a manœuvre needs practice to master without losing the model in a complete 180 degrees turn, but can be most effective in providing a means of losing height at the same time as increasing penetration and holding a definite course. It may call for a large number of rudder actions in a single flight, hence a relatively long escapement motor is necessary. Momentary rudder blipping is also a way of combatting a zoom.

A typical installation is shown in Fig. 23 utilising a standard escapement mounted in the middle of the fuselage—the best position for weight distribution. This also allows the escapement rubber motor to be brought to a convenient point at the rear, for withdrawal for winding with a wire hook fitted in a hand drill, or a simple mechanical winder. The escapement should be bolted to a ply bulkhead and the driven wire loop connecting with the crank connected by a rigid rod to the rear crank. This long length of connecting rod should never be wire, as this is both unnecessarily heavy and too prone to vibration effects. Hard balsa strip about $\frac{1}{8}$ or $\frac{1}{4}$ in. square is the best material for the rod, with wire fittings bound to each end as shown.

Operation of the linkage is self-evident. The rocking motion of the loop engaging the escapement crank (or pin) is translated into a similar rocking motion of the end wire crank. This engages in a hairpin loop of wire secured to the rudder. There should be enough clearance for the wire to slide in the hairpin loop without binding, but not excessive clearance so that the rudder can chatter. The same applies to the loop fitting at the front end.

The actual degree of rudder movement produced can be varied by adjusting the attitude of the hairpin loop—and thus the effective moment arm of the wire crank—reducing the moment arm to reduce rudder movement and vice versa. The rubber motor-winding plug can be fitted in the rear of the fuselage or on one side, as most convenient.

There are, of course, many possible variations on this theme. It may be preferred to operate the rudder control via a bellcrank movement and a push-pull rod connected to a rudder horn. This scheme is illustrated in Fig. 24, using a normal escapement. The main thing to bear in mind is that the simpler and more direct the linkage is the more foolproof it is likely to be; the less the slop and friction in the system, the more positive the control action.

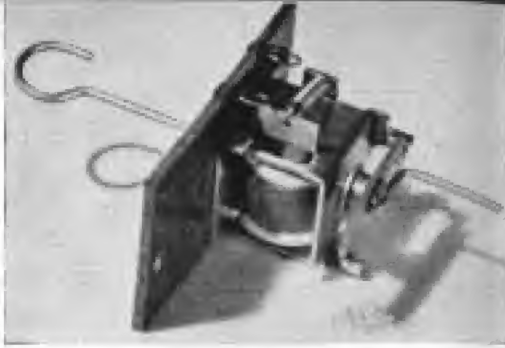


David Boddington's "Quest" a 36 inch design for single channel with aileron or rudder control is APS Plan no RC 915 5/6 from Aeromodeller Plans Service, 13/35 Bridge St., Hemel Hempstead, Herts.

Before you fly . . .

Before launching it is essential to tune and check the operation of the receiver *at long range* with the motor running.
Photo right shows a model about to be launched and the correct operation of the equipment is again being verified. Never launch if there is *any* doubt about radio reliability.

Above: the MacGregor tone transmitter Mk. II

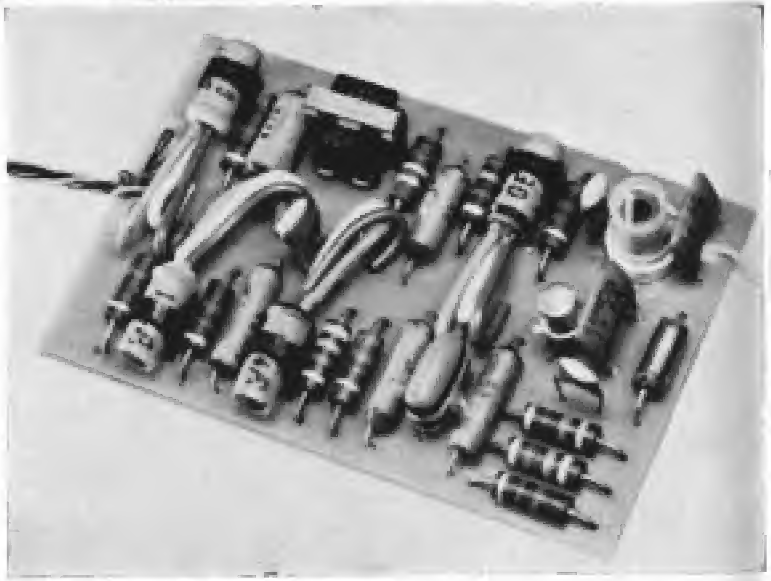


TRANSMITTERS RECEIVERS AND ACTUATORS

Right: the Min-X "Compact" sub-miniature 3 volt all transistor relay-type super-regen. receiver.

Left: Babcock light weight escapement—ideal for the smallest R/C models using sub-miniature receivers.

Below: the Ektronic lightweight compound escapement, featuring three "hold" positions plus "quick blip."

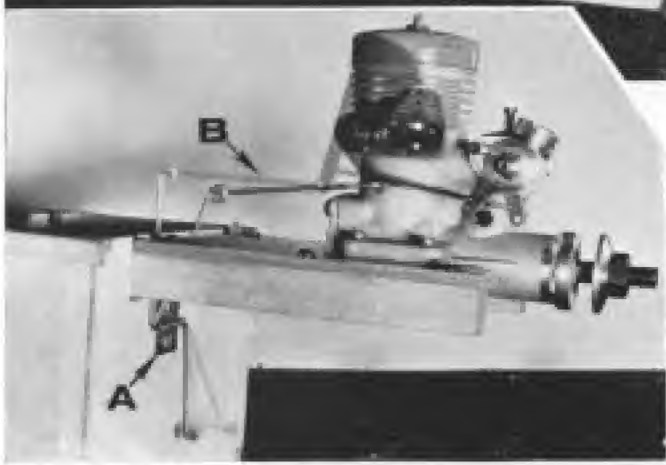


Right: the Terrytone Mk II receiver sold in kit form. Very easy to build and recommended to the beginner who wishes to save money by constructing his own equipment.

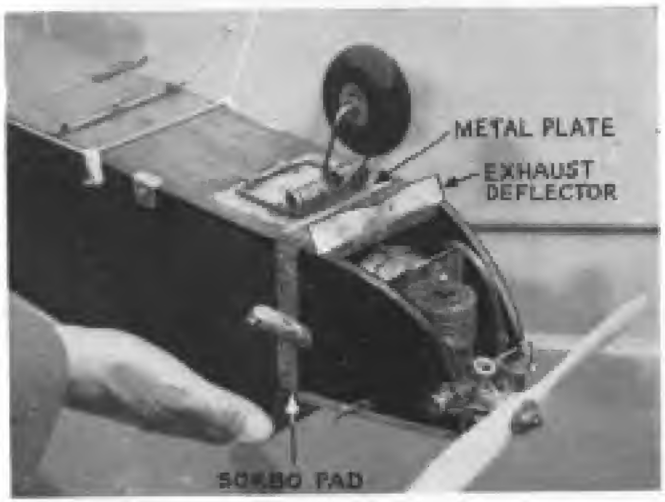
Above: R.C.S. sub-miniature all-transistor relayless receiver $1\frac{5}{8}$ x $1\frac{1}{4}$ x 1 in., $1\frac{1}{2}$ oz.

Left and Below: Kraft sub-miniature receiver, very compact and neat.

Right: Japanese miniature escapements. S-2 "progressive" escapement weighs $\frac{3}{4}$ oz., Electrical "trigger" switching circuit signalled by quick blip. K-2 is a compound escapement of similar overall design plus wiper-type separate switching circuits. Overall size $1\frac{1}{2}$ x 1 x 1 in.



Engine control installation. Above, the coupling rod from the actuator to the operating arm mounted on the engine bulkhead. It is *essential* that the coupling rod is insulated from the actuator. Left: by dint of trick photography the final linkage to the engine is shown in both the open and closed position.



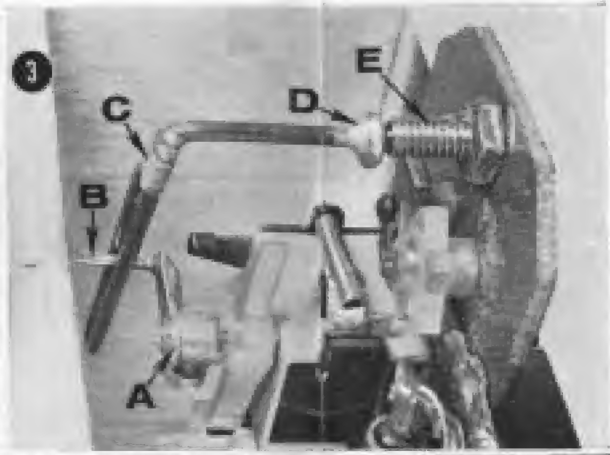
This close-up of the nose of a design by Harry Stillings shows several novel features. Between the cylinder head and the exhaust deflector is the fuel tank and the entire motor "pod" is insulated from the rest of the airframe by a $\frac{5}{8}$ in. thick pad of sorbo rubber. Note also the substantial coil-sprung nose wheel.

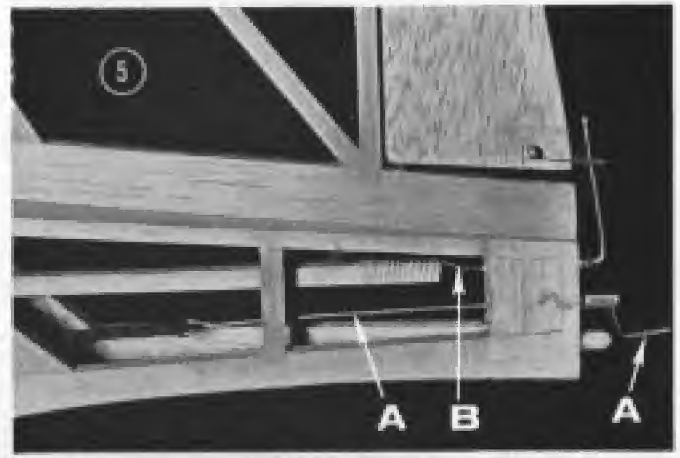
TWO POPULAR DESIGNS FROM "AEROMODELLER" PLANS RANGE

Above: Dave Platt's "Half Tone," a simple, rugged, beginner's design of 38 in. wingspan for 0.8 c.c. motors that has given hours of flying fun to those who have built it. Copies of the plan (M.A. 357) cost 30p each.

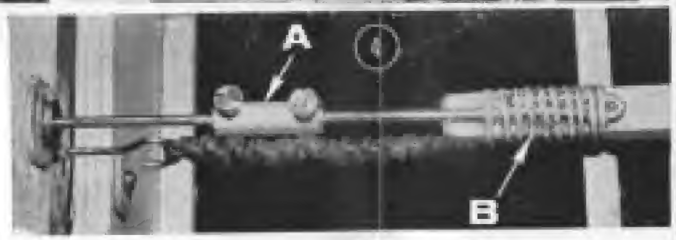
Somewhat larger, W. Lister's "Pika" is also an ideal beginner's design of 58 in. wingspan which is suitable for 2.5-3.5 c.c. motors. Copies of the plan (M.A. 352) cost 40p each.

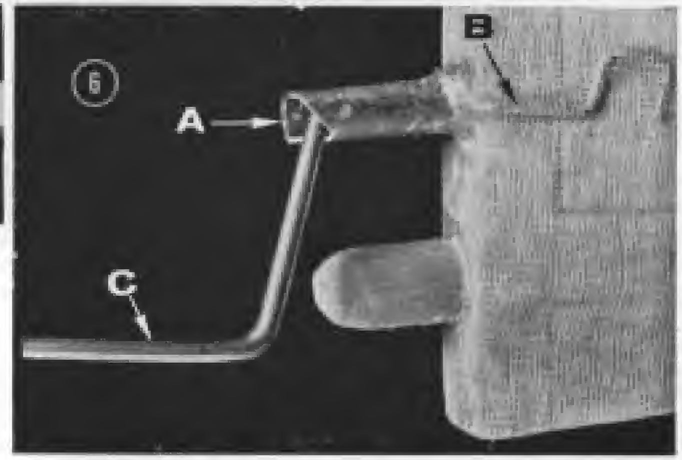
The above plans can be obtained direct from Aeromodeller Plans Service, 13/35 Bridge St., Hemel Hempstead, Herts.



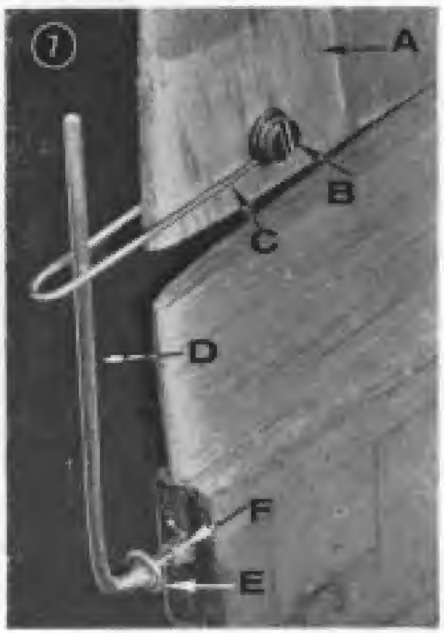


1. With nearside sheeting omitted this photo shows the additional basic structure required to convert a free flight model for radio installation. "A" is the receiver bulkhead and "B" the actuator mountings.
2. The rear face of the mounted rudder actuator showing:—torque rod "D" rubber motor, and the leads ("A") to the clockwork throttle actuator.
3. Front face of the mounted actuator showing crank "A" and "B" torque rod yoke "C", soldered washer "D" and brass bushing, "E".
4. Torque rod coupling ("A"). Wire is doubled back ("B") before binding to ½ in. sq. torque rod to prevent twisting.

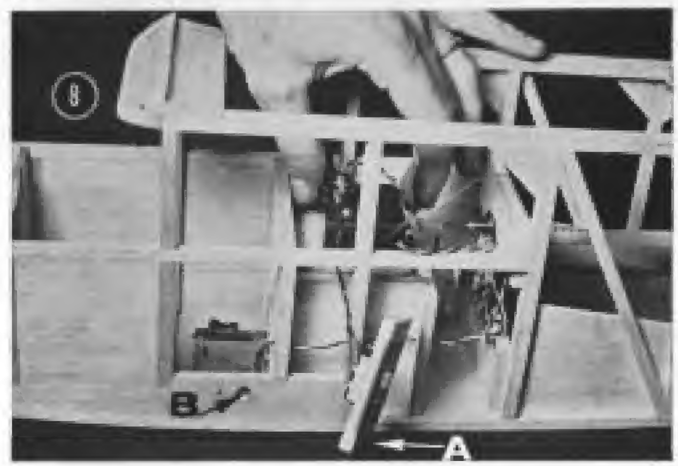




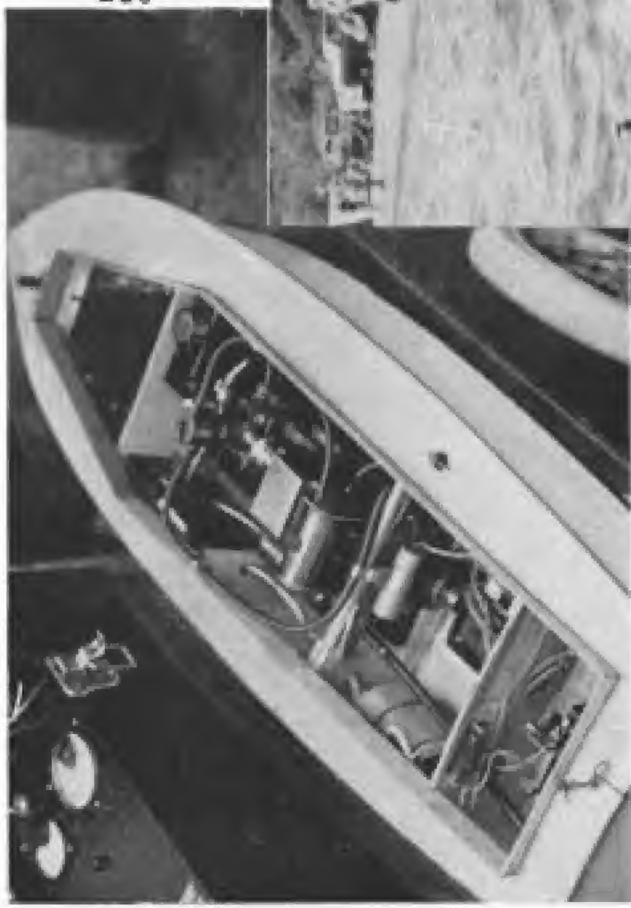
Photographic details of equipment installation and linkages in a model . . .



5. The "works" end. Wire "B" is bound to torque rod in similar manner to above. "A" is cranked wire for winding the rubber actuator motor.
6. A close-up of the winding crank ("C") shown in photo 5. Note how the brass bush is cut away to prevent the motor unwinding. Reinforcing bandage cemented over wire "B" which is soldered to tube "A".
7. The rudder yoke and torque bar rear end bearing, shown in greater detail "A" bandage—"B" 6 B.A. nut and bolt securing adjustable yoke ("C"). "D" torque rod rear end "E" soldered washer and "F" brass bush.
8. The "radio room". Switch panel "A" is not yet fixed in place, and the receiver, wrapped in foam plastic is being pressed into its box made of ½ in. sheet. The winding hole for the clockwork driven engine actuator is shown at "B".



Below: Various exercises are devised at regattas to test operator's skill. This shows a cabin cruiser being directed by radio to a miniature harbour.



Above: Layout depends on available hull space. The receiver is placed forward of the engine. Astern are the batteries and steering gear.

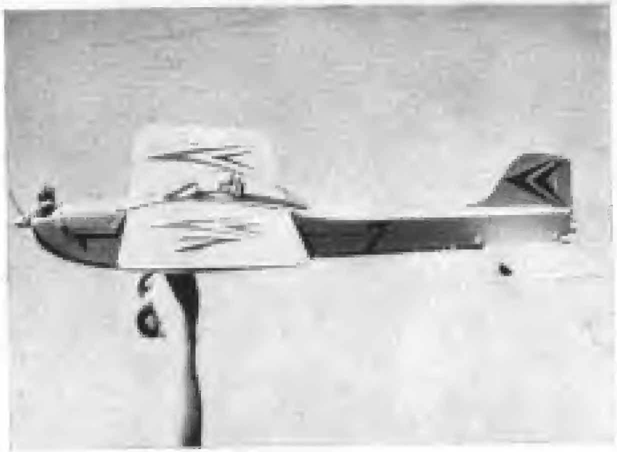
SOME COMMERCIAL DESIGNS

old and new

Left: The Graupner "Consul," the first commercial kit to make extensive use of foam plastic in its construction.

The 45 in. span Gremlin Skyslinger is an ideal trainer and uses any engine between 1 c.c. and 3.5 c.c. This example is fitted with Metz 3-channel radio for selective left and right rudder and sequential throttle control.

Right: A Veron "Robot" in its uncovered state. The functional, rugged, yet attractive design is clearly shown in this photo where it is being held by its builder, Derek Ormon.



Ever popular "Gasser" by Ken Willard at left is a very aerobatic s/c design available from APS as Plan RC 744 price 40p

Below: Veron's Tipsy "Nipper," an attractive scale model which flies well.

Above: Veron kit designer Phil Smith starts up his scale model of the Cessna Skylane—the first scale kit in this country designed specifically for radio control.

Right: originally designed as a free flight sportster, Doug. McHard's 30 inch span Wee Snifter (plan No. M.A. 340 price 30p post free) was successfully converted to single channel R/C and with a .75 c.c. engine it provided snappy and realistic flights for the minimum cost.

Above: Another Dennis Thumpston model is this Fokker EV which also uses Wright equipment and placed third in the single channel event at the 1960 British Nationals against competition from non-scale models—a real achievement.

Right: Built from commercial plans, by D. J. Bannister, this Fokker D-8 makes an ideal R/C subject and has long been a favourite among free flight builders.

Dennis Thumpston holds his beautiful Sopwith "1½ strutter." This machine uses the New Zealand designed Wright radio equipment with a relaytor.

A little originality . . .

Right: The inherent stability of deltas makes them ideal s/c models. Here E. Setz of Switzerland is shown with the model which won him the single control class at the 1959 International R/C meeting. Note the nose rudder.

Below: Peter Demuth, of Pforzheim, Germany, with his unusual R/C tail-less model. Span 82 in. O/D single channel receiver. Graupner Telematic servo. Enya 09 engine and 8 x 4 nylon prop.

Above: Nice semi scalish pusher design by Sq.-Ldr. Eric Cable. Radio is easily accessible under cockpit canopy.

Left: Biplanes have a special fascination and make ideal radio subjects. Performance can often better that of more orthodox designs.

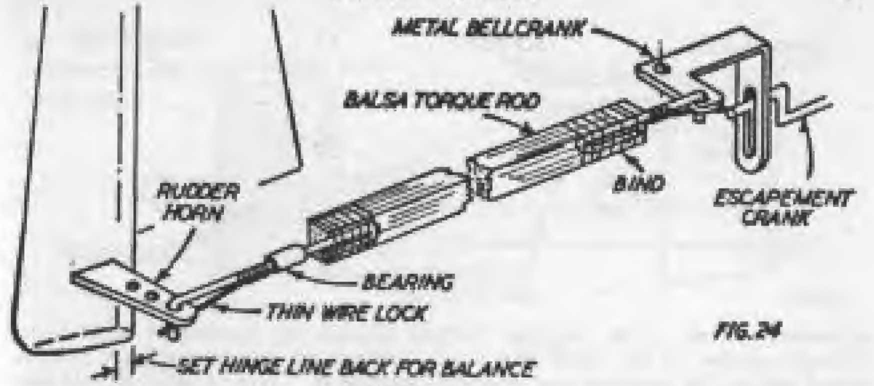


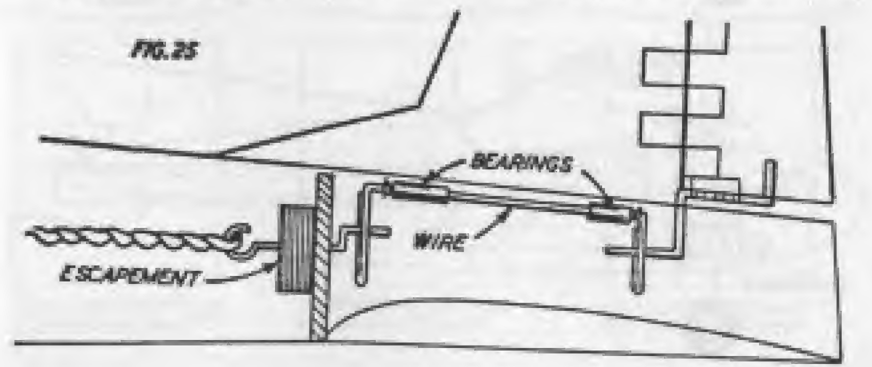
FIG. 24

In some cases, too, it may be preferred to locate the escapement in the rear of the fuselage, when all-wire linkage may be employed as in Fig. 25. This may be a cleaner installation on a relatively large model using a compact, lightweight escapement. It is not a good idea for smaller models, where the escapement weight has to be balanced by a much larger weight forward, if the model is not to turn out tail heavy. Also it brings the free end of the rubber motor into an awkward position for winding, usually necessitating removal of the wing.

There is another disadvantage of all-wire linkages. Any appreciable length of wire tends to act as an aerial and thus pick up R.F. signals. Although these may be extremely minute, the rubbing of an electrically active wire part over another (as in movement of the linkage) can generate electrical noise or interference which can be picked up by the receiver and cause it to chatter. There are two methods by which such noise can be eliminated. The simplest is to insulate all rubbing wire (or metallic) parts from electrical contact with a piece of plastic tubing or radio sleeving over the wire. The other is to bond all the wire parts with a flexible lead soldered in place as shown in Fig. 26. This effectively shorts out the source of interference. For proper bonding this lead should theoretically also be connected to an earth point relative to the receiver—e.g. the common battery negative. This may cause more trouble than it is worth, however, if the bonding is not complete, so is not recommended as general practice.

Receiver and battery mounting is, of course, quite independent of the

FIG. 25



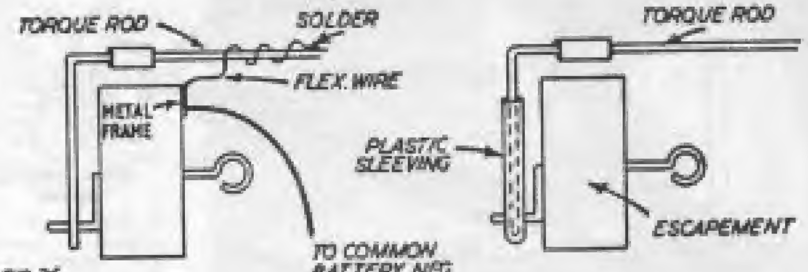


FIG.26

actuator system. The receiver should always be mounted behind the batteries so that in the event of a crash landing the batteries cannot be projected against the receiver and possibly damage it. The receiver should also be flexibly mounted to minimise the transmission of vibration to it from the engine, and to provide a measure of shock protection in a crash or heavy landing.

There are many possible systems. In some cases experienced modellers prefer to sling the receiver on rubber bands (Fig. 27) although this is not usually considered necessary with modern units. Other methods are to strap the receiver down with rubber bands (or cement directly) to foam rubber pads either on the bottom of the fuselage or the back of a main ply bulkhead (Fig. 28). Alternatively the receiver may be mounted on a ply-

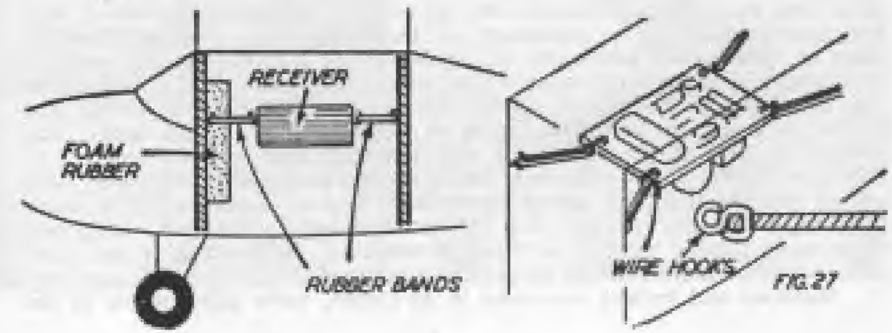


FIG.27

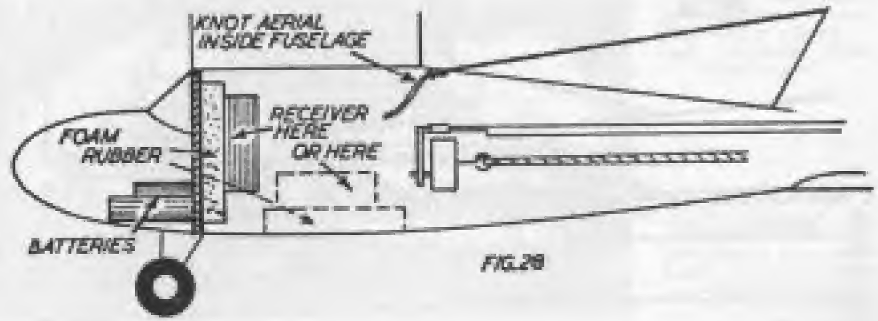


FIG.28

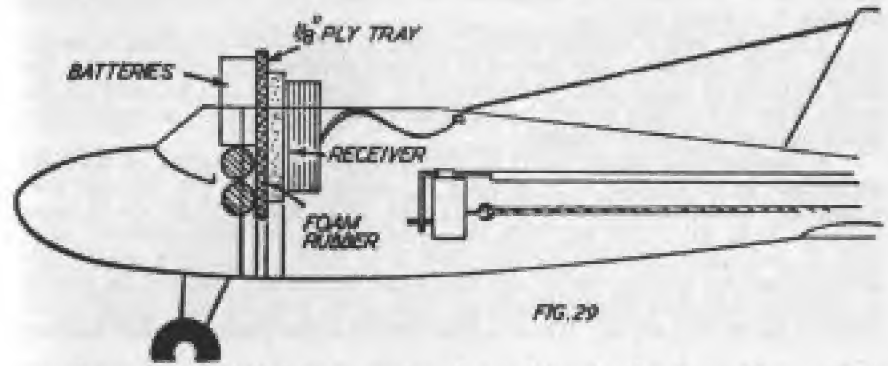


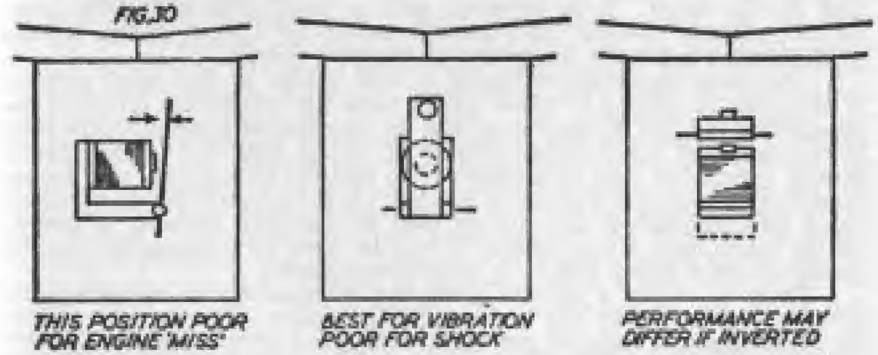
FIG.29

wood tray which slides into grooves formed in the fuselage sides, making the whole unit easy to remove as required. In this case the batteries may be strapped to the front of the ply tray (Fig. 29). Yet another method is to mount the batteries independently in a separate compartment in front of the forward cabin bulkhead—particularly advantageous in bringing the battery weight well forward but making the batteries rather more difficult to get at. No shock absorbing mount is normally used for the batteries, the main requirement being that they should be anchored in place securely and with all connections positively made.

A further point regarding receiver mounting. The foam rubber (or, more usually, foam plastic) used should not be too stiff and rigid, nor too flexible. Foamed plastic, in fact, is not the best material for the job, although commonly used. The right degree of sponginess required is that given by about 1 in. thickness of foam rubber of the type used for mattresses.

There is also the question of the best way round to mount the receiver. The source of engine vibration is the up-and-down movement of the piston. An engine which misfires, however, will give a sideways kick to the fuselage. To minimise the effect on the relay it is therefore desirable that the relay armature movement should lie in a plane at 90 degrees to these vibration movements. This means that the best theoretical position for the relay armature is vertical when mounted with the armature pivot at right angles to the fuselage (see Fig. 30). This, incidentally, also minimises gravity

FIG.30



effects on a non-balanced armature but renders the relay most liable to damage in a crash landing.

The most useful second control, using a compound actuator, is motor speed. This demands the use of a further escapement operated via the third position or quick blip. A normal S.N. escapement can be used for the motor control but with its mechanical action rather differently arranged than when applied to rudder control.

A two-position (single arm) or four-position (double arm) escapement connected as in scheme A or scheme B, respectively, in Fig. 31 will give a normal intermediate throttle position and either low or high speed when signal is held on. This can only be switched via the third position, since high or low speed control positions have to be held. It is not a satisfactory arrangement for normal use in any case since for normal running the engine is partially throttled (control neutral) and both high or low speed when selected has to be held on. Thus rudder control is not available when holding

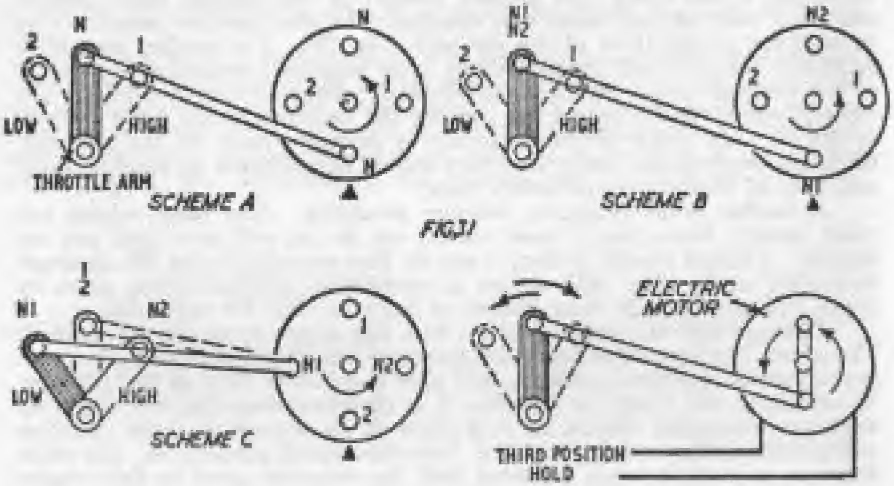


FIG.31

high or low speed. It is, however, used in some cases where the intermediate throttle position gives enough power for normal flying, making available extra power for stunts, or low speed for descent.

This basic limitation of having to hold a high or low speed position is overcome in scheme C which simply turns the mechanical action of the escapement through 90 degrees so that the two neutral positions correspond to low and high speed respectively. To change from low to high speed, or vice versa, it is then only necessary to trip the escapement, e.g., release as soon as the control position is selected. It is thus ideal for operating off quick blip, although it can also be used off the third position, of course. In the latter case, if the control is held on then an intermediate throttle position is held, giving effectively three-speed control.

There is usually a definite advantage in operating off the quick blip position, however, since this is selected more rapidly. Intermediate throttle (i.e., three-position throttle) can then be obtained by using a four-position non-neutralising escapement.

If a servo motor is used for throttle control movement, the third posi-

tion must be used. There are a number of ways in which such a control can operate :—

(i) Using a simple electric motor drive and mechanical linkage, as shown in Fig. 31, which is inched to the required throttle position progressively; according to the time the control position is held. This is not a satisfactory method for aircraft (although possible for boats) because it is difficult, or impossible, to judge where the throttle control position has stopped (or to stop without over-running the desired position, as judged by visual and audible response of motor performance).

(ii) Using a single channel servo with contact switching giving sequential control, viz. one-way-neutral-other-way-neutral (returning to neutral on release of signal). This has the same disadvantage as the use of an S.N. escapement in that the normal (neutral) throttle position is intermediate (half-way) and each extreme position for slow or fast has to be held on.

Nearly always the non-neutralising escapement will prove the best pro-

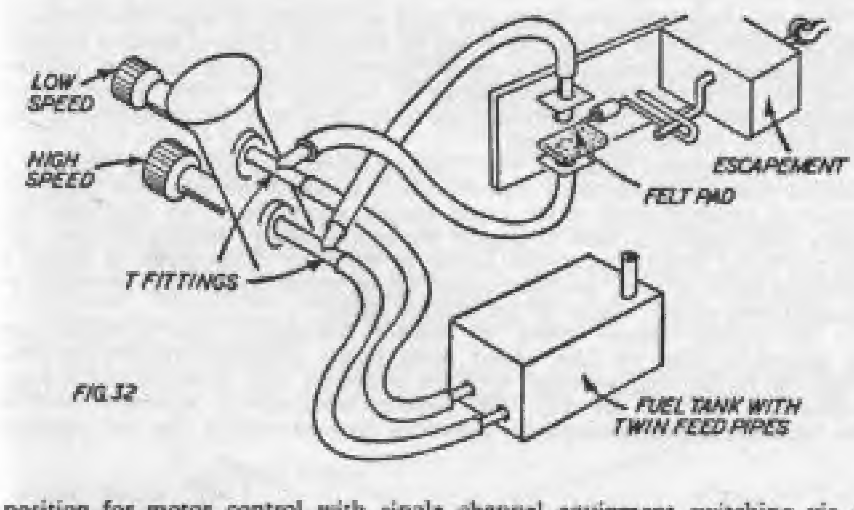


FIG.32

position for motor control with single channel equipment switching via a compound actuator.

Special escapements have been produced for two-speed control allied to twin spraybar arrangements, a typical unit being shown and described in Fig. 32. It may be preferable in this case to mount the secondary (motor speed) escapement in front of the firewall, although this will normally mean piercing the firewall to carry the rubber motor drive back into the fuselage and introduce a source of oil seepage. The alternative—mounting the secondary escapement in the cabin—can lead to excessive lengths of plumbing.

With throttle controls requiring push-pull movements to operate, the question is merely one of arranging a suitable mechanical linkage and the secondary actuator is almost invariably mounted in the main fuselage behind the firewall. The linkage is then taken through the firewall. A typical scheme is shown in Fig. 33. Note that vertical mounting of the escapement for direct linkage coupling is acceptable even if the resulting rubber motor length is short. This is because the throttle control will not be used all that number of times during a flight and thus relatively few turns are needed on the escapement motor. Even if the motor does run down and throttle control is lost, this would not endanger the model.

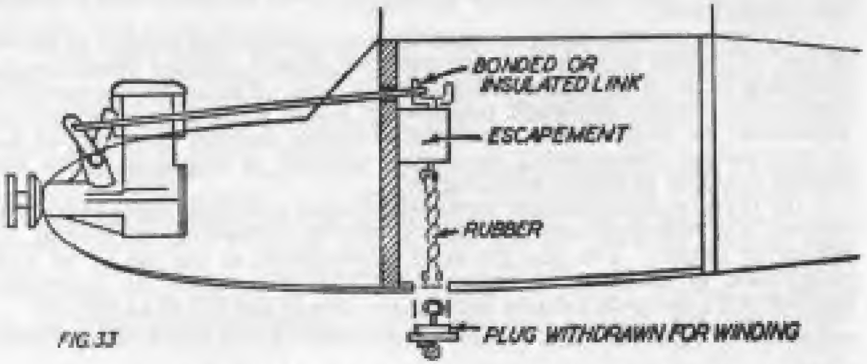


FIG.33

Connecting linkage is invariably rigid and usually all wire. To eliminate the possibility of interference, it would be advisable either to insulate or bond such linkages, as previously described, if the receiver is at all sensitive. Adjustment of travel can be accomplished by bending the wire to shorten or lengthen the stroke, incorporating any stops that may be necessary (if not included on the throttle system).

The compound actuator with third position and quick blip permits a further control service to be utilised, which is about the safe limit to go for practical single-channel work using simple equipment. In this case the quick blip control is used to trigger the motor control escapement and the normal third (holding) position linked to elevator. This gives, in effect, a selective elevator trim position, either up or down (not both), reverting to neutral position on release of the control signal.

A typical system using a Bonner Varicomp with elevator trip is shown in Fig. 34 (the added plate being specially designed to provide this facility and supplied with the necessary cam follower and linkage connecting the two drivers). Up elevator movement is normally selected for the third control position for enhanced manoeuvrability (e.g. for looping).

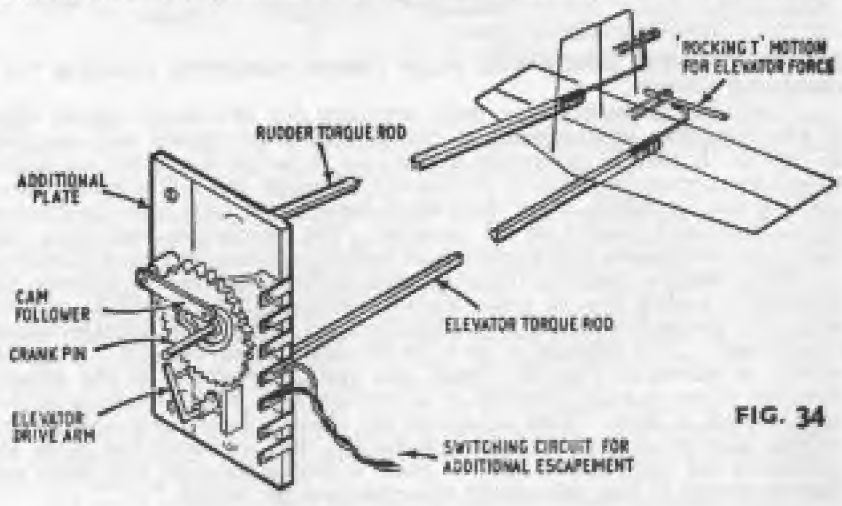


FIG. 34

Down elevator could equally well be used for improved penetration, if preferred, simply by reversing the end link.

It should be noted that with kick elevator, as this is called, the elevator should be aerodynamically balanced to relieve the escapement of load, otherwise the power available from the escapement motor may not be sufficient to displace the elevator against the airstream in flight.

Although this system is highly practical and provides three positive *selective* controls and one non-critical selective-sequencial control—and seems very easy to master on a bench test—it demands considerable skill and experience to handle successfully under flight conditions when things happen rapidly. It is about the limit in what can be mastered with press-button switching—and certainly a limit to simple multiple control systems operated by single-channel equipment, which are the subject of this present booklet.

A certain simplification of the problem is possible using specially designed control boxes—known as bleep boxes—which relate straightforward mechanical movement of a control stick (or similar hand-operated switch) to the required signal switching. In other words, movement of the control stick to a desired control position operates mechanical or electro-mechanical switching gear to send out the appropriate number of pulses and hold—or automatically give the quick blip signal if that switching position is selected. Bleep boxes can offer a definite advantage in this respect, provided they do not skip or miss a particular signal. Some are very reliable, others are not. And a bleep box which gives wrong signals puts the pilot in a worse position than having accidentally applied a wrong signal by the normal push-button switching.

Another control system which should be included under simple single channel operation is coupled aileron and rudder. The rudder is a vicious control; ailerons are not. Most turns with multi-channel controls are accomplished by aileron movement alone, and are much smoother as a consequence. Ailerons are also the most suitable control surfaces for producing controlled rolls.

Since adding another separately selected control movement is not practical with single-channel equipment, independent aileron control is not a

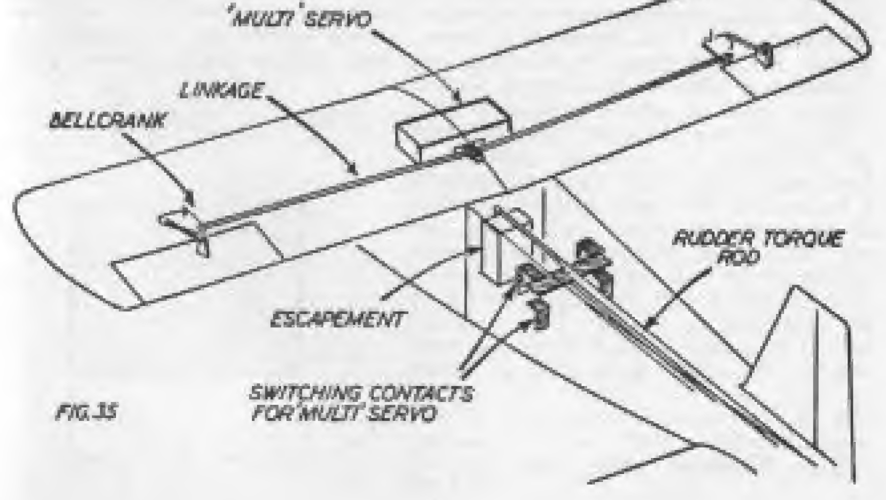


FIG.35

proposition. It has been suggested, and tried, in place of rudder as the primary control but with little success. It is readily possible, however, to operate ailerons and rudder together as a common control, with the possibility of considerable benefits. For example, the rudder action can be reduced, relying on the coupled aileron movement to assist in producing better, smoother turns. In many manoeuvres, however, ailerons and rudder may require to be moved in opposition—even in turns (e.g. a little top or opposite rudder to keep the nose up)—so a coupled aileron-rudder system will not necessarily improve the scope of manoeuvrability.

It is strictly necessary to operate ailerons via a self-centring motor-driven servo (most conveniently mounted in the centre of the wing). To couple ailerons and rudder movement it is then only necessary to arrange that the mechanical movement on the basic escapement corresponding to a rudder control position operates a switch (or a set of switching contacts) to energise the aileron servo in the same direction (see Fig. 35 and also Fig. 38, Chapter VII). Thus right rudder would also automatically switch the servo to left aileron down, right aileron up; and left rudder the reverse aileron operation—both rudder and ailerons always returning to neutral on release of signal.

Proportional control movements are also possible, using single channel equipment, where the main signal is pulsed or otherwise modified to provide a much more sophisticated control response. In such cases a pulse box or bleep box is used at the transmitter end to provide suitable signal modification by mechanical or electronic switching with specially designed servo-motors at the receiver end. All such systems come outside the scope of simple single channel work and most have particular limitations in any case.

CHAPTER VII

Boat Systems and Vehicles

RADIO control applied to model boats offers tremendous scope with quite simple systems, principally because boat controls are non-critical. That is to say control failure or mis-direction is only likely to cause inconvenience (or embarrassment), and not damage to the craft. The radio controlled boat therefore offers an opportunity of enjoying the hobby with a minimum of cost and a minimum of risk to the equipment involved.

Main application is to power boats, driven either by electric motors or small internal combustion engines (water-cooled diesels, mostly, in this country, although glow motors—air cooled and water-cooled—are favoured in America). Radio control may also be applied to yachts both for steering and sheet handling. This, however, represents a rather more specialised demand and outside the scope of this chapter.

The single-channel receiver can provide all the controls necessary to manoeuvre a model power boat, with many additional controls available by means of sequence switching. Sequence switching is perfectly acceptable with boats, even if not satisfactory for multiple controls on aircraft models. The main control, as with aircraft, remains the rudder. Next in order of preference is motor speed and motor reverse. Then can follow minor services, such as lights, firing miniature torpedoes, raising and lowering an anchor, etc., etc.

Because of the heavier loads, a servo is necessary for rudder operation. Some smaller, light models may use escapements successfully for rudder control, provided the rudder is balanced. Even a balanced rudder on larger models, however, really demands a servo motor.

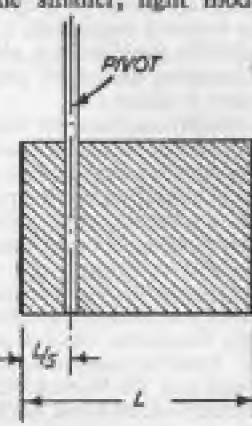


FIG. 36

Rudder balance is provided by locating the hinge line or pivot point back from the leading edge. In the case of a flat plate the centre of pressure is approximately one-fifth back from the leading edge (see Fig. 36). If the rudder is pivoted about this line it will be fully balanced and require a minimum of force to displace it to one side or the other. A pivot point farther aft will unbalance the rudder and also tend to make it inefficient. A pivot point slightly forward of the fully balanced position generally gives maximum rudder efficiency.

Because of the slow response time of a marine model to control movement —and the non-critical nature of the control—proportional or progressive controls are quite feasible as opposed to full on-off or bang-bang controls used on aircraft. With simple progressive control the rudder is inched on a certain amount according to the time the signal is held on and stopped in the estimated position required, judged by the response on the part of the model. True proportional control produces a control movement in proportion to a movement of a control stick, knob or wheel and is not practical with simple single-channel equipment unless a "bleep" box is used.

Using a single channel motor servo as a progressive control actuator, it cannot be self neutralising. It simply stops where it is when the control is taken off. In fact an ordinary electric motor is all that is needed for the servo in this case (Fig. 37). This is suitable for controlling slow and medium speed

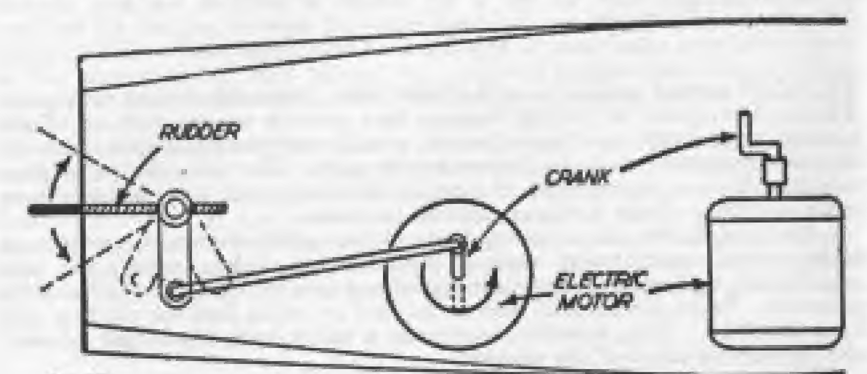


FIG.37

craft (e.g. electric motor powered) but experience has shown that a self-neutralising rudder is virtually essential for high speed craft (e.g. diesel powered). Many operators, too, may find that they prefer a self-neutralising rudder even on the slower speed boats.

Usually the self-neutralising motor servo can be modified to progressive action (and vice versa) simply by rearrangement of connections or a change of contact disc. It can therefore be tried out both ways to see which gives the most practical control response. If the servo motion is specific—e.g. either progressive or self-neutralising, and not capable of changing over with simple modification—it is important to purchase the right type initially.

The electric-powered boat offers more control possibilities than the diesel-powered counterpart, although normally restricted to lower speeds of operation. Both types of power unit can be throttled—the former by reducing the current or voltage to the motor and the latter via a conventional aircraft-type throttle—but only the electric motor can be reversed. Reverse is practical with a diesel if a suitable gearbox is fitted, but no such gearboxes are produced commercially for model work.

To realise additional control services a compound type actuator is required yielding a third switching position independent of the two rudder movements (right or left). If such a position is not available on the servo, then a compound escapement can be used, connected to the receiver, and employed purely as a switch to control the rudder servo motor and give the third selective switching position (see Fig. 38). Note that a compound actuator can be used to operate switching to:—

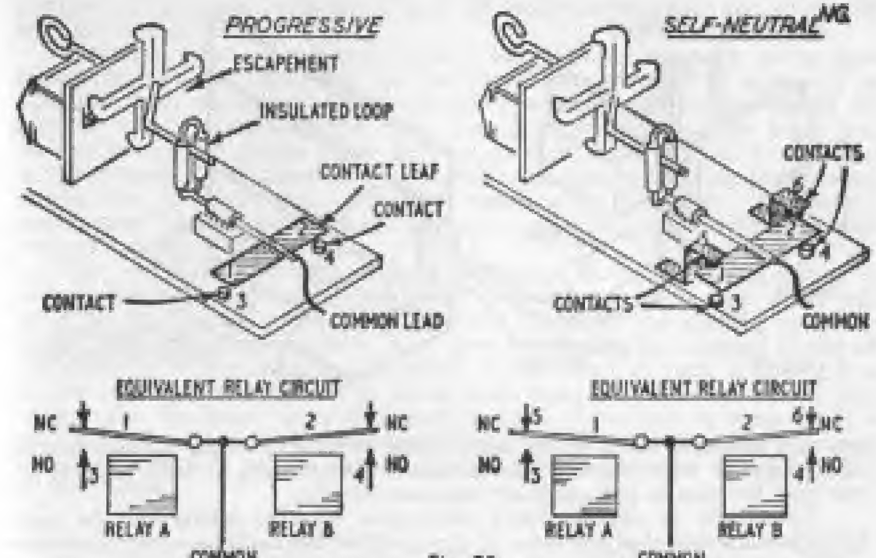


Fig. 38

(i) Reverse a simple electric motor used as a rudder servo to give selective direction and progressive movement.

(ii) Correctly switch a multi-servo connected to work progressively.

(iii) Correctly switch a self-centering multi-servo.

On some craft it may be possible to use the compound escapement movement for operating the rudder direct, as previously mentioned.

The third switching position can then be used for additional control services in several ways, viz:—

(i) Motor speed control—via a two-position, two-neutral escapement, as with aircraft motors for diesel (or glow motor) speed control.
—via a motor or motor-servo driving a potentiometer to vary the current to the main electric motor power unit.
—via a two-position escapement switching out part of the main motor battery supply for speed control on the main electric motor.
—via an SN escapement which in neutral gives normal forward speed; in one control position half speed (e.g. by switching out half the main battery); and in the other control position reverse by reversing the polarity of the main battery connections. Half speed and astern are thus selected in sequence on the third position.

(ii) Sequence operation of multiple controls.
In this case the third position or quick blip on the main actuator is used to step a non-neutralising actuator or sequence switcher. Each position is connected to and thus capable of activating a separate control service—e.g. motor speed, astern, running up a flag, etc., etc. Any particular control response must be selected by switching through the appropriate sequence. Individual control circuits may be actuated by separate electric motors or escapements, as appropriate.

Although the use of a sequence switcher appears complicated it is a very practical system and one which can give excellent results. In its simplest form the sequence switcher could provide three positions (in sequence) correspond-

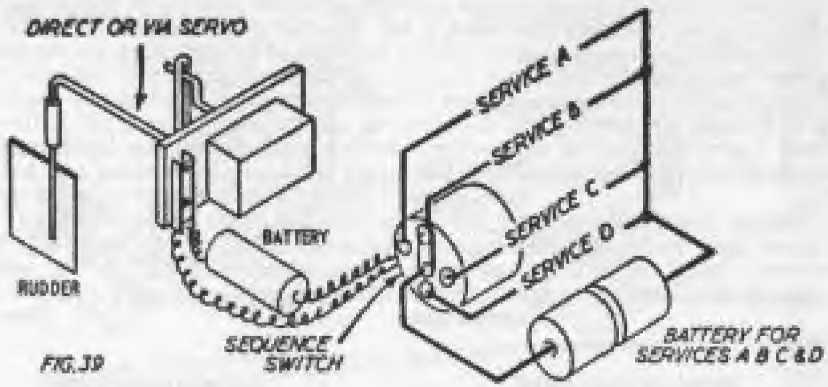


FIG. 39

ing, say, to motor start, motor stop, motor reverse (with an electric motor). This, together with selective rudder control (progressive or bang-bang as the case may be) should give complete manoeuvrability.

There are, of course, many alternative schemes which can be used. Largely it is a matter of ingenuity in arranging for the necessary control services which can be operated through simple third position switching without interfering with the main rudder action. A third position control which has to be held, for example, will mean that rudder control is not available until it is released. More elaborate systems generally employ bleep boxes to pulse the main signal and corresponding matching actuators. Simple systems, such as described, will usually give comparable results and probably better reliability.

Regarding installation, a boat hull is far from the ideal place for locating radio control gear because of the risk of it getting wet, or fouled by oil from diesel motor (the exhaust on diesels should always be directed overboard via an oil trap, in any case, to avoid mess inside the hull). The receiver, being light, is generally best placed near the bows forward of the engine compartment (see Fig. 40). It can be protected against moisture by enclosing it completely in a polythene bag, making off closely around the leads with a rubber band. Any tuning adjustments necessary would have to be made through the bag, which is not easy and may be impossible in some cases unless the bag is cut at that point and, say, bound to a tube fitted over the tuning point. The servo motor operating the rudder is generally best placed aft and fairly near the rudder to reduce the length of linkage required. Its switching contacts are very sus-

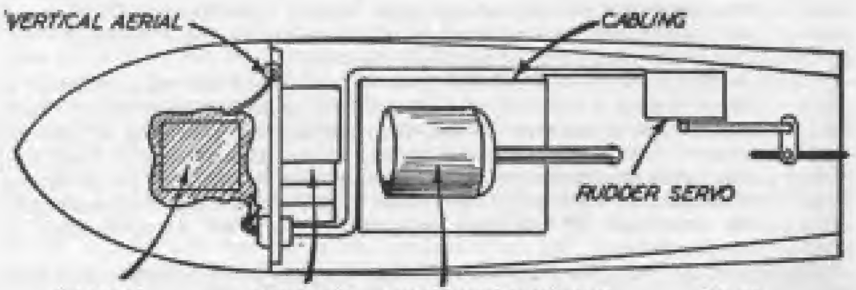
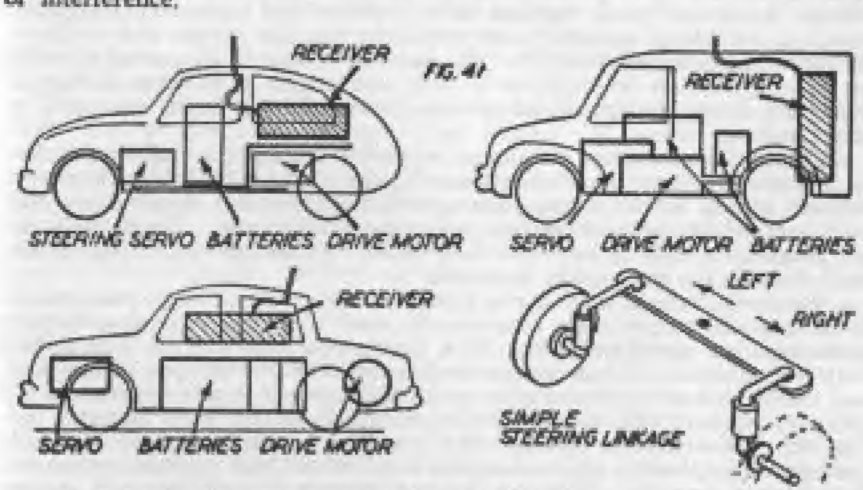


FIG. 40

ceptible to corrosion, particularly in a salt water atmosphere, and so should be inspected regularly.

Batteries represent a major weight (larger sizes normally being preferred for boat operation) and can be placed as convenient or necessary to trim the boat correctly. All intermediate wiring and cabling should be kept as neat as possible, preferably lashed or bound in cable form and secured to suitable points in the hull rather than being allowed to lay loose in the bottom. The possibility of metallic linkages generating interference should also be considered, calling for bonding or insulation. All electric motors may have to be suppressed, too, in order to avoid interfering with the receiver (see Chapter VIII).

The aerial usually represents a problem. Fortunately long range is seldom required with model boats and so a shorter aerial than usual will often be satisfactory. Preferably, however, it should be erected vertically rather than strung horizontally (e.g., between masts) thus taking it out of the plane of wiring running the length of the boat (as well as giving it a greater effective height). The aerial lead from the receiver should not, incidentally, be taken out with the other leads if the unit is wrapped in a polythene bag or similar waterproof container. It should always emerge separately, clear of all the other wiring, again to eliminate any possibility of interference.



Model vehicles represent rather similar problems to model power boats, with steering as a main control and motor speed as the chief additional control required. Very similar methods can be adopted, therefore—e.g., using a motor servo for steering via suitable mechanical linkage and sequence switching for motor stop, start, reverse, etc.

Space is usually much more restricted, often calling for cramming of the components. This may well increase the possibility of interference due to the proximity of electric motors and live wiring to the receiver—hence complete bonding may be essential (and even the use of bonded sheathing on wiring runs).

General descriptions are of very little use in this case since each vehicle type, size and design represents a specific problem or set or problems to be sorted out by the constructor. Some typical arrangements are shown in simplified diagrammatic form in Fig. 41, which emphasises some of the major requirements.

CHAPTER VIII

Installation and Operation (General)

THE simple radio control receiver is called upon to operate under somewhat critical conditions, as well as often being subject to mechanical vibration and mechanical shock. It, and the actuator, are essentially precision devices (or should be, if they are to be reliable) and hence the installation which is completed around them should be equally precise and carefully completed with regard to detail. The majority of installations require wiring up to complete and the inclusion of such components as switches and meter jacks (not always necessary) which may have to be purchased separately as accessories.

Whilst slide switches are almost invariably employed as on-off switches on models they are not always a satisfactory choice. Slide switches with definite wiping action contacts are generally reliable but those which rely on a snap action (without wiping) can prove troublesome. Toggle switches are generally unreliable and excessively bulky. Miniature toggle switches are hard to come by, and usually expensive.

Receivers using a single battery supply require only a single pole switch. A double-pole switch may, however, be used to switch the servo battery separately (but simultaneously). If a double-pole switch is used to switch both high tension and low tension receiver batteries (on one pair of contacts) and the servo battery on the other pair of contacts, it should be used in the common negative lead in the former case to disconnect *both* batteries (see Fig. 42). Theoretically, on most valve circuits, it is only necessary to switch the low tension battery since when this is cut off no high tension current can flow through the valve. However, there are dangers in leaving the high tension battery potentially live and it could discharge through a faulty electrolytic capacitor with the set apparently switched off.

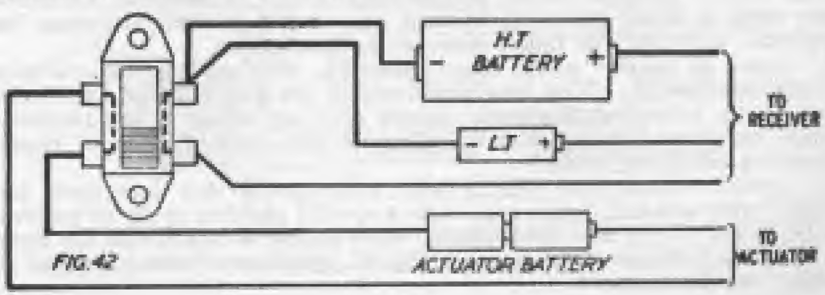


FIG. 42

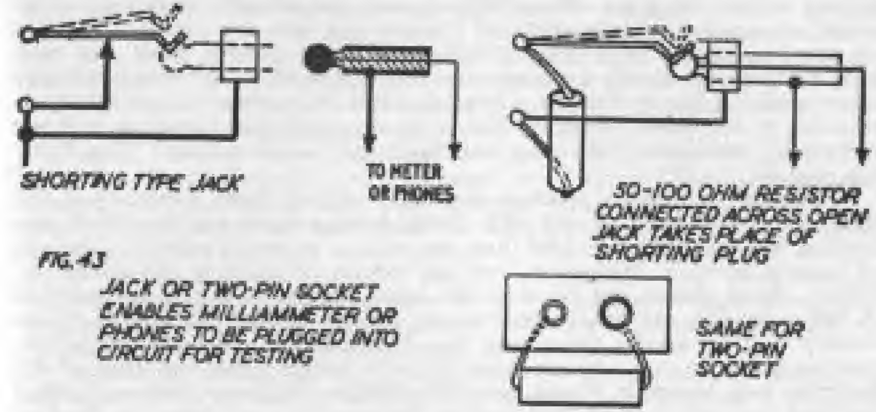


FIG. 43

wiring with sound soldered joints is essential. This job cannot be done too well. Probably a majority of faults which develop in service are directly traceable to faulty wiring. It is not enough that the system works

Wiring is worth a chapter on its own. Suffice it to say that proper after wiring up. The wiring—and all soldered joints in particular—should be beyond reproach.

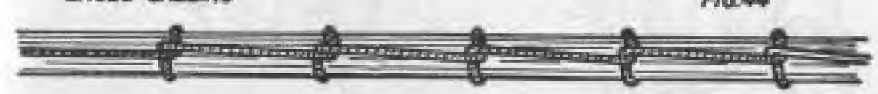
For convenience, wiring is commonly terminated in multi-pin plugs (from the receiver) fitting multi-plug sockets (to which actuator and battery wiring is connected). American practice is to leave the modeller to complete all soldered joints (e.g. receivers are not normally wired to a plug, as supplied). British (and Continental) practice is to supply the receiver wired to a plug leaving only the external circuit wiring to be completed on the socket. In the latter case the size of plug and socket is fixed by that supplied. Where no plug and socket is supplied with the equipment there is a definite temptation to use one of the sub-miniature types (although expensive). These, however, do not always produce reliable connections, nor are they as easy to solder to. The larger standard size multi-pin plugs and sockets are usually best for most installations, even if appearing unnecessarily bulky. The extra weight involved is negligible.

Wire size and type is also most important. Stranded wire should always be used for external circuit wiring and not smaller than 12/·004 size (see Table on page 52). The resistance of wiring increases quite rapidly with decreasing diameter size and a long run of very thin wiring can cause a considerable voltage drop. This is also a point in favour of keeping wiring lengths as short as practical—bearing in mind that wiring must never be drawn taut between fixing points as this stresses the soldered joints unnecessarily and is asking for early failure. Cable runs should also be laced (Fig. 44) or bound with plastic sleeving, etc. Flat strippable colour-coded wires, now available in this country, offer an easy way of making cabling without the necessity of binding individual wires together.

Normally different coloured wires are used for different services to make

LACED CABLING

FIG. 44



it easy to sort out leads when checking, and also identify leads from a receiver or actuator without resort to tracing back into the circuit. There is no standard colour code adopted for model radio control work, but each manufacturer will specify the connection or purpose of the individual coloured wires used on his equipment. Typical usage for general circuit wiring is detailed in the Table, although this is by no means fixed practice and not necessarily consistent with some manufacturers' use of colours. (See Table on page 60.

General installation arrangements have already been summarised and described in Chapters VI and VII. Some further notes may be added concerning battery connections for these are often a source of trouble. The use of battery boxes is convenient, but the contact obtained is not always reliable. Brass should not be used for contact springs as it is not reliable. A heavy landing can cause bent contact springs through the inertia of the battery bearing against them, and loss of connection. Snap-on type connectors (soldered to leads) are standard with certain types and sizes of dry batteries (see Appendix 5) and generally reliable. However, internal contact between layer-type small high voltage batteries is not always as good as desired, and a rubber band wrapped round the battery to pull the ends together is often a wise precaution.

Ordinary press studs soldered to wires and batteries do not make good, reliable snap-on connections. Pigtails soldered to batteries with twisted connection to battery leads are likewise unreliable and should never be used. If in any doubt, soldered connections are best—soldering the battery lead either directly to the appropriate battery terminal or to a pigtail soldered to the battery. Never take chances with battery connections. It just is not worth it. And always make sure that there is no direct " pull " on the battery connection which could cause the joint to fail under vibration.

Battery installation and connection problems are minimised using DEAC batteries for all services where the batteries consist of one or more packs of individual cells made up to the required voltage. Such batteries are not available with press-stud end fittings, taking snap-on connectors. It is thus only necessary to solder matching press-stud fasteners to the leads and snap onto the battery for connection. It is, however, a wise precaution to fit a stout rubber band around battery and connections, as shown in Fig. 44a, to guard against any possibility of the connection vibrating off.

The use of DEASs is confined essentially to low voltage batteries (7.2 volts being a normal maximum DEAC battery voltage, although larger batteries can be made up). This covers all the range of actuator voltages likely to be required, and the power supply for all-transistor receivers.

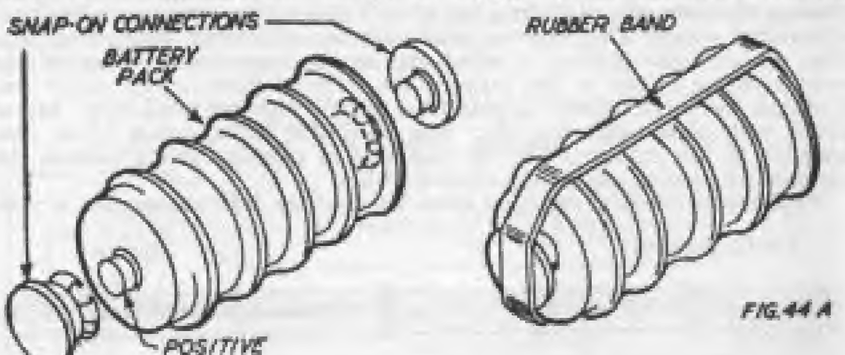


FIG.44 A

Valve-transistor receivers, however, will require a high tension battery of higher voltage (usually 22.5 volts). This is available as a standard type with press-stud terminals, again simplifying connection. Thus battery boxes can usually be eliminated entirely, the batteries simply being press-stud connected and located in a suitable compartment. Packing around with lightweight foam plastic then holds them securely in place.

Power " packs " have also been produced for receiver/actuator units, consisting of transistorised units powered by a single DEAC battery and igving both high tension (22.5 volt) and low tension (1.5 and 3 volt) outputs. Performance of the " pack " is kept up to scratch by recharging the single DEAC battery, as necessary. The main application of such power packs, however, is for " multi " installations and valve-detector receivers where at least two separate servo batteries are required, together with receiver H.T. and L.T. supplies. They are expensive and have no particular advantages for single-channel installations.

Operation, setting up and tuning adjustments are usually specific to individual receivers and covered by manufacturer's instructions. Where a receiver has both a sensitivity and a tuning control the two are interdependent to some extent and alteration of one may affect the other. With most modern receivers, however, a single tuning control only is used and the set can be tuned merely by finding the extreme range of adjustment over which the receiver will respond (as marked by the clicking of the relay or operation of the actuator) and then setting the adjustment to a mid position.

If receiver and transmitter are too close, the receiver may be swamped, when tuning is obviously impossible. This is not likely to occur over a distance of a few feet, however, with the transmitter aerial removed or retracted, which is a convenient distance for initial tuning. The mean setting for the tuning control is then found by trial, as shown in Fig. 45.

It is absolutely necessary to repeat a similar tuning check at range. Recommendations for distance for the range check vary widely. Some authorities may speak of 300 ft. or less being more than adequate since effective range is considerably increased once the model is in the air. Others recommend 1,200 ft. or more—at which distance it is practically impossible to observe hand signals and establish the necessary liaison between the person holding the transmitter and the one holding the model.

On average, a range check at 200 yards should give satisfactory range in the air for normal flying—bearing in mind that it should be doubled under such conditions and 400 yard range is about the limit of visual observation

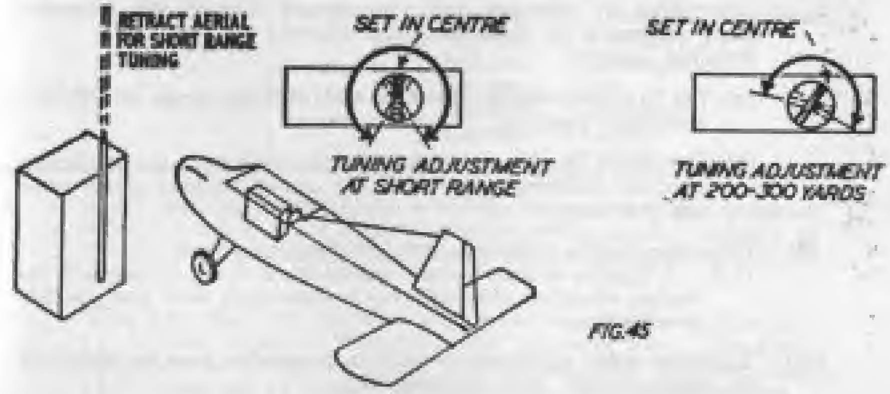


FIG.45

as to which way the model is pointing and can be controlled effectively anyway. A 300 yard range check would be better, but not all receivers may give this ground-to-ground range (yet provide satisfactory range in the air). A range check at over 300 yards is usually quite unnecessary—except to measure extreme ground-to-ground range of the receiver—and does not contribute anything useful in the way of setting up or tuning.

The first thing to establish when conducting a range check is a system of signals whereby both people concerned know what is happening or what action is required—e.g. as long as the person holding the model keeps his back to the person holding the transmitter, no signal is required. When he turns to face the transmitter a signal is wanted and the type of signal can be indicated by an outstretched arm—e.g. to the right for right rudder, to the left for left rudder and overhead for third position (assuming that the model incorporates a compound escapement).

Tuning will probably be modified at a distance—e.g. typically less adjustment either side of the mean position to lose the signal. The actual mean position itself may also be different to that originally found. This is because there may be modifying conditions introduced—not only distance but the fact that the transmitter is now ground coupled in the manner in which it will normally be used (resting on the ground or held in the hand) and radiating from its full aerial length.

At extreme range—i.e. the distance at which the receiver begins to lose the transmitter signal and cannot be tuned to pick it up, the position of the receiver aerial relative to the transmitter may show an effect. Broadside on, for instance, a signal may be picked up, but lost if the model is turned through 90 degrees. Equally, a signal picked up when the model is held overhead may not be picked up at the same distance when the model is on the ground. These are quite natural effects and will not interfere with the normal operation of the receiver, unless they occur at a relatively short range.

It remains now to check receiver operation both at short range and distance with the engine running. This is to check that vibration does not upset the receiver relay or actuator, causing chatter; or that mechanically generated noise is not interfering wtih the electronic circuit. This type of fault is all too common and must be cured to produce a reliable model. Possible causes are:—

(i) Engine-receiver combination not suitable—i.e. the receiver is susceptible to vibration and just cannot tolerate the vibration level generated by that particular engine.
Possible cures:

(a) Try to reduce engine vibration with different prop. or different propeller position.

(b) Try more flexible mounting for the receiver; try mounting receiver different way round (e.g. at right angles to the existing position).

(ii) Excessive engine vibration—try (a) above as a cure.
N.B. A flexible engine mount is seldom, if ever, effective in reducing vibration although this is sometimes used and claimed as effective.

(iii) Improper relay adjustment—hold in properties may be improved by readjustment. (See Chapter IX).

(iv) Electrical interference—can be checked by seeing if the receiver operates correctly (e.g. using a meter) with actuator circuit disconnected and dead.
Possible cures:

(a) Spark suppression on relay contacts (see Chapter IX).

(b) Suppression on servo motors (see Chapter IX).

(c) Bonding or insulation required on mechanical linkage.

(d) Aerial badly placed relative to current carrying wiring (e.g. parallel to the fuselage). Try with aerial strung up to a wing tip at right angles to fuselage wiring; or try a vertical rigid wire aerial.

Virtually similar descriptions apply to boat models, except of course, that less operating range is required. It should be remembered here that a range check should be carried out with the boat in the water, as this may considerably modify the tuning. A range check carried out over land with the model held, or resting on the ground, may not give anything like the same range from land to water.

RECOMMENDED WIRE SIZES

(For General Wiring)

SPECIFICATION*		12/·004	14/·0076	
Wire Dia. S.w.g. equivalent*	42	42	36	36 or larger
No. of Strands*	Less than 12	12	14	Less than 14
Suitability	Not Recomm.	For General Wiring but not Escapement Circuits	Better for General Wiring Recomm. for Escapement Circuits	Not Recomm.

* Small diameter stranded wire is usually designated by two numbers separated by a /. The first number refers to the number of strands and the second the diameter of the individual strands or wires.

With fine wires the diameter size is usually expressed directly—e.g. 12/·004 means 12 strands of ·004" diameter wire. The s.w.g. equivalent is sometimes used to designate wire diameter—e.g. 12/42, meaning 12 strands of 42 s.w.g. or ·004" diameter wire.

TYPICAL AND SUGGESTED COLOUR CODING

DUTY	COLOUR
Battery Negative Earth	Black
High Tension Positive	Red
Battery Positive	Red or Yellow
Low Tension Positive	Blue
Aerial	*Pink*
Relay Armature	White
Relay Back Contact (NC)	*Blue*
Relay Front Contact (No)	*Green*
Actuator Leads	*Yellow or Brown* *Orange or Blue*
Common Negative (On servo Batteries, sometime Transmitter Batteries)	White
Transistor Base Connections	Green

Italic colours are purely arbitrary choice

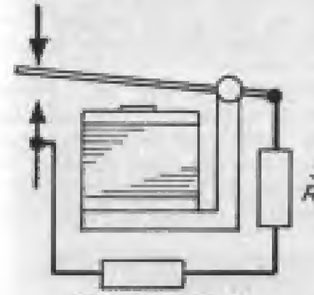
CHAPTER IX

Faults and " Trouble-Shooting "

CERTAIN types of faults may be specific to particular equipment—e.g. certain receivers may start to give inconsistent results almost as soon as the battery voltage starts to fall off. Others are of a more general nature and applicable to most single-channel radio control equipment. For convenience of reference these are summarised in the Table.

Interference effects generated in the model itself can usually be eliminated by bonding or insulating the metallic components concerned, as previously described. Arcing across relay contacts (or actuator contacts) require rather different treatment, however.

Here the cure is to quench or suppress the arcing current, either with a combination of a 47 ohm resistor and .05 mF. capacitor connected across the contacts as shown in Fig. 46; or using a diode for the same purpose, usually connected across the escapement coil (Fig. 47). This sup-



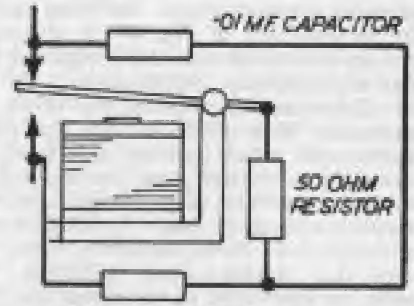


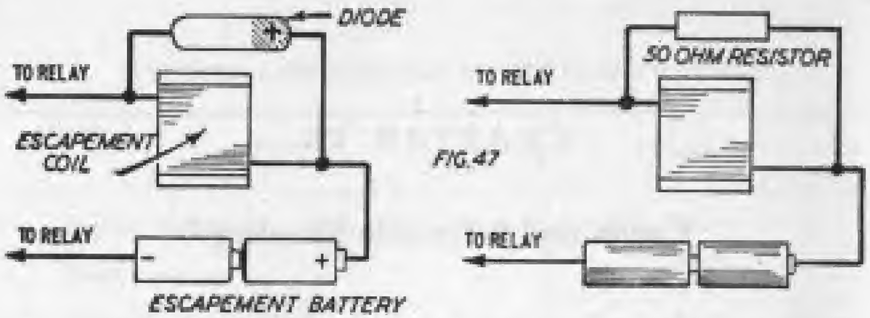
FIG. 46

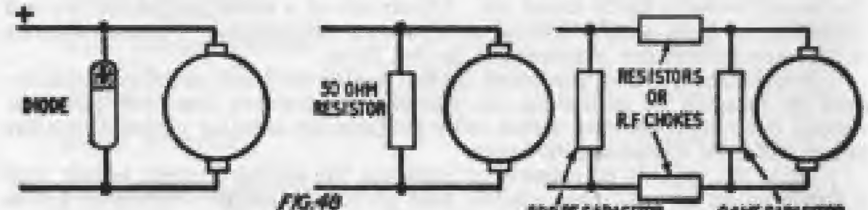
presses R.F. interference, but is possibly more effective in the case of A.F. interference For this reason it may be preferred where a tone receiver is concerned.

Note that where the back contact of the relay is also used (as in quick blip switching) suppression is required across both pairs of contacts, although this only calls for the use of a second capacitor.

Since a diode acts as a rectifier in offering a high resistance one way but negligible resistance in the other, it must be connected with the right polarity to work effectively as a suppressor.

An actuator coil benefits from suppression to absorb the back e.m.f. surge when the circuit is broken (largely instrumental in producing the spark or arc at the relay contacts). In this case a 50 ohm or 100 ohm resistor connected in parallel across the coil is usually effective, as an alter-

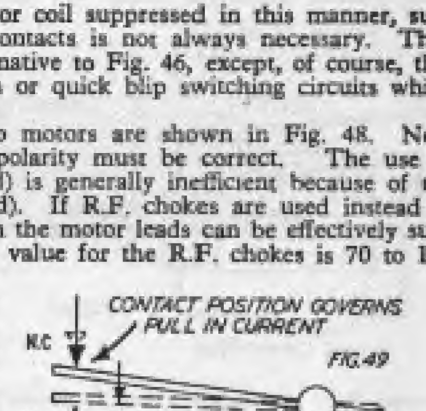


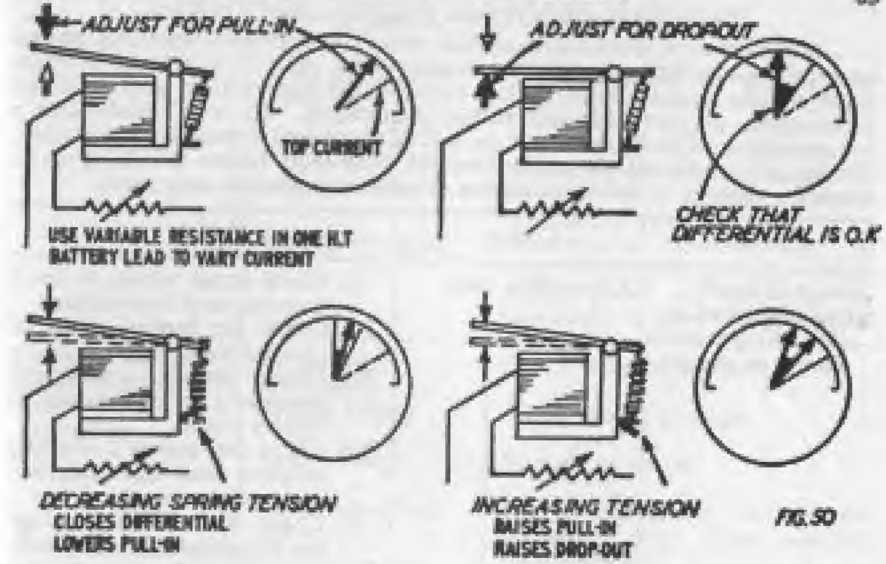


native to a diode. With the actuator coil suppressed in this manner, suppression applied across the relay contacts is not always necessary. Thus the arrangement of Fig. 47 is alternative to Fig. 46, except, of course, that it does not cover the third position or quick blip switching circuits which may need separate suppression.

Solutions for suppressing servo motors are shown in Fig. 48. Note again that if a diode is used the polarity must be correct. The use of resistors in series (one in each lead) is generally inefficient because of the power loss (voltage drop introduced). If R.F. chokes are used instead of resistors, however, all radiation from the motor leads can be effectively suppressed with little loss. A suitable value for the R.F. chokes is 70 to 100 microhenries. Note, however, that even this system cannot suppress radiation generated in the motor itself. In many cases, therefore, particularly when the receiver is extremely sensitive, no amount of suppression is completely effective in rendering the receiver circuit interference-free. There is little that can be done in such cases except to avoid the use of a motorised actuator.

Relay adjustment is detailed in Figs. 49 and 50. On all commercial receivers relay adjustment is pre-set and should not normally be altered.





Initial adjustment may, however, change with time, or as the result of knocks received, and require resetting. The basis of relay adjustment is quite simple but it needs experience to arrive at optimum adjustment for there are a number of possible settings at which the required pull in and drop out settings may be achieved.

The back or upper contact, against which the relay armature rests when the coil is not energised, determines the pull in current required. Bending this contact in (or screwing in, if the contact is adjustable) moves the armature nearer the pole so that it will pull in at a lower current; and vice versa.

The lower contact against which the armature bears when pulled in governs the drop out current. The farther the armature is held away from the pole the earlier it will drop out (i.e. the higher current at which it will drop out; and vice versa again. If the armature is allowed to pull in very close to the pole, drop-out will be drastically delayed. If it actually touches the pole it may not drop out at all until some considerable time after the current has been switched off due to residual flux holding it down. Thus the armature should never be allowed to touch the pole piece, nor should it be allowed to come too close, otherwise the differential (difference between pull in and drop out currents) will be too high. On the other hand, the closer the armature is to the pole when pulled in, the stronger it is held.

Adjustment, by varying the contact settings, consists of arriving at a satisfactory pull in and drop out current, with an acceptable differential. The pull in current must leave sufficient margin below the normal top current to provide satisfactory hold and allow for the fact that the top current may fall with range (and also with ageing batteries). The drop out current must also be high enough to provide a leeway to be above the influence of momentary variations in bottom current.

Spring tension further modifies the settings—an increase in spring tension shifting the operating points to higher current values, and vice versa, as well as possibly affecting the differential. Follow Fig. 50 as a typical method of arriving at a suitable adjustment.

TROUBLE-SHOOTING CHART—RECEIVERS

Manufacturers instructions should always be followed regarding wiring connections, setting up and tuning, battery sizes, etc. In a majority of cases faults will be found due to (i) low batteries (ii) poor wiring, poor soldered connections, or poor plug and socket connections. On *new* installations a common cause of faulty operation (or lack of operation) is *incorrect connection.* Wiring circuits should always be checked *thoroughly* before switching on as otherwise damage to valve, transistors or other components may result.

Fault	Cause	Action
Does not work when switched on (No idling current shown on meter)	Connection fault	(i) Check actual wiring to see if it agrees with instructions. (ii) Check for broken wires or poor soldered joints. (iii) Check battery connections (especially spring pressure in battery boxes). (iv) Check that switch is working properly and not defective due to dirt, etc. (v) Check that shorting plugs are in position (where used).
	Circuit fault (component)	Faulty component. Faulty valve. Note: it may be a faulty valve connection due to valve having been displaced from its base.
Does not respond to transmitter (Idling current shown on meter when switched on)	Weak batteries	Check actual battery under load with suitable voltmeter—preferably after the battery has been on for 2-3 minutes. An absolute minimum load voltage for satisfactory operation is 0.8 times the nominal battery voltage (e.g. in the case of a 22½ volt battery, 0.8 × 22½=18 volts as measured on load). Replace batteries if approaching this minimum load voltage figure.
	Faulty tuning	Re-tune against transmitter (transmitter on) at short distance and at range. Do not attempt to tune near possible sources of interference—e.g., an iron shed, fence, etc. In the case of aircraft : tune at range with the model held at shoulder height. In the case of boats : tune at range with the model in the water. In both cases the transmitter should be used in the normal operating position (i.e. hand held or standing on the ground).

Fault	Cause	Action
	Relay adjustment faulty	Check that relay *is* working—e.g. by switching receiver on and off. If working, readjust to circuit specification or manufacturer's recommended 'pull in' and 'drop out.' If not working, suspect mechanical fault in relay.
	Transmitter fault	Transmitter batteries may be weak or transmitter faulty, transmitter aerial not connected or extended, or poor connection.
Relay or escapement "chatters" (Motor not running)	Faulty relay adjustment	Check relay adjustment.
	Critical tuning	Check tuning at range.
	Faulty tuning	Re-tune as above.
	Transmitter fault	Check transmitter for correct operation, e.g. from another transmitter.
	Outside interference	
Relay or escapement "chatters" (Motor running)	Engine/propeller combination	Check propeller balance or change propeller.
	Receiver mounting	Improve shock-resistant mounting of receiver or mount in a different attitude.
	Faulty adjustment	Relay adjustment may be faulty or weak batteries giving poor 'hold in.'
	Electrical 'noise'	Insulate or bond metallic linkages.
Lack of range	Faulty adjustments	Check relay operating points and differentials against recommendations. Specifically check top current at range (batteries may be weak).
	Critical tuning	Re-check tuning.
	Weak batteries	Check receiver and transmitter batteries under load.
	Charge of aeria	Check that aerial charge is correct.
	Transmitter fault	Check transmitter operation independently.

TROUBLE SHOOTING CHART—TRANSMITTERS

If possible, the source of the fault should be isolated—e.g., in the receiver circuit, actuator circuit or mechanical linkage. All the faults listed may be caused by a receiver fault and if confirmed can be traced through the receiver Trouble-Shooting Chart. The remaining possible sources of trouble then refer to common faults which may develop in the escapement or mechanical linkage systems.

Fault	Cause	Action
Apparently no signal (No reading on field strength meter)	Faulty adjustments	Check against manufacturer's specifications.
	Circuit disconnection	Check for broken or disconnected wiring, fault in keying lead or switch.
	Circuit fault	(i) valve may be displaced from its holder, or broken. (ii) component failure (more difficult to trace without specialised knowledge—return transmitter for check and service if necessary).
Weak signal or lack of range (Low reading on field strength meter and short range)	Faulty adjustments	Receiver may not be correctly tuned to transmitter.
	Aerial fault	(i) Check that aerial is proper length (also that the loading coil is incorporated, where specified). (ii) Check that aerial is properly mounted (e.g. good connection at base). (iii) Check that joints are not oily or dirty on telescopic aerial. (iv) Check that aerial is not earthing through faulty socket or moisture on socket.
	Weak batteries	Check batteries under load. Load-voltages should never be less than 0.8 times nominal battery voltage.
	Unfavourable operating conditions	(i) Transmitter on damp ground with variable "ground coupling" effect. (ii) Output affected by presence of overhead wires, etc.
Control surface of actuator "chatters"	Fugitive vibration and excessive slack in linkages	Change propeller or balance propeller to reduce vibration. Reduce "Free" movement in linkages.
	Escapement motor too strong—causes escapement to 'skip' under vibration.	Replace with smaller section motor or reduce number of turns supplied.
	Escapement motor wound wrong way	Immediately apparent as it occurs on winding the escapement motor.
	Escapement faulty	Pawl or detent not properly raked or set.

Fault	Cause	Action
Control surface of actuator sticks "on"	Escapement motor too strong—locks escapement	Replace with smaller section motor or use less turns.
	Escapement motor unwound	Enough power for one movement but not return.
	Escapement fault	May be burr on pawl or detent. Check and adjust for proper action.
	Excessive friction	Check linkage for freedom of movement.
Control surface of actuator sticks "off"	Escapement motor unwound	Check that it is rewound the **correct** way.
	Escapement motor too weak.	May stick "on" or "off."
	Weak actuator batteries	Insufficient to energise coil. Replace.
	Excessive friction	Too much "binding" for escapement motor to move linkage—so free up.
	Excessive aerodynamic load	Use aerodynamic balance to cure. Note : Excessive aerodynamic load at high speeds may equally well lock a control position "on" by distorting the linkage and causing binding.
Controls do not operate	Weak actuator batteries	Check voltage under load.
	Actuator circuit fault	Isolate actuator circuit and check operation independently. (i) Possible wiring faults or disconnections. (ii) "Dry" solder joints. (iii) Actuator coil fault.
	Dirty contacts	Check and clean as necessary. Re-adjust contact pressure.
	Damaged contacts	Contacts may be pitted, burnt or even welded by using excessive actuator voltages (this also includes relay contacts)
	Mechanical failure	Check for binding linkages, broken or seized hinges, etc.
Controls inter-act	Electrical interference	Suppression or bonding may be needed, if not already used.
	Weak batteries	Additional load to second actuator too much for battery capacity.

SINGLE-CHANNEL CONTROL SYSTEMS
AIRCRAFT

Control	Selection	Actuator	Model Size Span	Model Size Motor
Rudder	Sequence	Simple Escapement Self Neutralising	up to 54"	up to 3·5 c.c.
Rudder	Selective	Compound Escapement Self Neutralising	30" to 54"	1 c.c. to 3·5 c.c.
Rudder	Sequence	Simple Single-Channel Motor Servo	42"–48" 48"–54"	1 to 1·5 c.c. 1·5 to 2·5 c.c.
Rudder	Selective	Compound Single-Channel Motor Servo	48"–54"	1·5 to 3·5 c.c.
Rudder plus Engine Speed	Selective	Compound Escapement with 'Quick Blip' and Secondary Escapement	42"–54"	1·5 to 2·5 c.c.
Rudder plus Engine Speed	Selective	Compound Single-Channel Motor Servo and Secondary Escapement	48"–54"	1·5 to 3·5 c.c.
Rudder plus 'Trip' Elevator	Selective	Compound Escapement with 'Trip' Action on third position	up to 48"	up to 2·5 c.c.
Rudder plus Elevator	Sequence	Cascaded Escapements	Not recommended	
Proportional Rudder	Direct* (proportional)	Proportional Motor type	48"–54"	1·5 to 2·5 c.c.

* Must utilise 'pulse box' connected to transmitter

SINGLE-CHANNEL CONTROL SYSTEMS
BOATS

Control	Selection	Actuator	Remarks
Rudder	Sequence Selective	Simple escapement Compound escapement	Suitable for small, light craft only
Rudder	Sequence Selective	Simple Motor Servo Special (compound) Motor Servo	
Rudder plus Engine Speed	Proportional* Sequence	Proportional Servo Compound acutator	(i) With secondary actuator linked to Diesel or glow engine throttle (ii) Operating rotary switch with electric motors
Rudder plus engine stop-start-reverse	Sequence	Compound actuator	Additional movement linked to mechanically operated switch or special contacts on actuator

* Must utilise 'pulse box' connected to transmitter

Receiver	*Manufacturer*	*Type*	*Size (inches)*	*Wt. (oz.)*	*Tran-sistors*	*Working voltage*	*Batteries required. (Ever Ready quoted)*	*All-up weight (Rx. + batteries) (oz.)*	*Current drawn (mA)*		*Price*
									Idle	*On signal*	
Emco Ace (British)	Emco of Coventry, 62 Lower Ford St., Coventry	Relayless tone	2½ × 3½ × 1	1½	4	4·5V	3 × U7	3	0·65	300	£11.19.6
Carrier Wave II (British)	MacGregor Industries, Station Wharf, Langley, Bucks.	Relayless Carrier Wave	3½ × 2 × 1½ (caseless)	1½	3 + valve	22·5V (HT) 1·5V (LT) 4·5V (output)	B122 (HT) U7 3 × U7	4⅞	(HT) 1 (LT) 100 (Act) 0·05	1·2 100 300	£3.10.0
C.S. 511 Honey Bee (U.S.A.)	C. & S. Distributors, 13400–12 Saticoy St., North Hollywood, California, U.S.A.	Relayless tone	1¾ × 1½ × ¾ (caseless)	¾	4	3V	2 × U7 or 3·6V 225 DKZ. DEAC	1⅜	6	325	£3.19.0 (kit) £4.19.0
Controlaire 5 (U.S.A.)	World Engines Inc., 8206 Blue Ash Road, Cincinnati, Ohio, U.S.A.	Relayless tone	1 5/16 × 1½ × 9/16 (caseless)	¾	4	3V	2 × U7 or 3·6V 225 DKZ. DEAC	1⅜	3	200 to 400	$7.98 (kit) $13.98 (ass.)
Gemini (British)	Derritron Radio Ltd., Chapel Lane, High Wycombe, Bucks.	Relayless tone	1¾ × 1½ × 1½	1½	6	4·5V	3 × U7 or 4·8V DEAC	3	1·65	350	£15.15.0 with Tx.
Kraft K3VK (U.S.A.)	Ace Radio Control, Box 301, Higginsville, Missouri, U.S.A.	Relayless tone	1 11/16 × 1 × ¾ (caseless)	¾	4	3V	2 × U7 or 3·6V DEAC	1⅜	2	150	£4.19.6 (kit) £5.19.6 (ass.)
LT3 (U.S.A.)	Citizenship Radio Corp., 810 East 64th St., Indianapolis 20, Indiana, U.S.A.	Relayless tone	2½ × 1½ × ¾ caseless)	1	4	3V	2 × U7 or 3·6V DEAC	2	3	300	$22.95 (U.S.A.)
MDL (U.S.A.)	Citizenship Radio Corp.	Relayless tone	1 × ¾ × 11/16 (caseless)	½	4	3V	2 × U7 or 3·6V DEAC	1½	8	300	$24.95 (U.S.A.)
Minimac (British)	MacGregor Industries	Relayless tone	2 × 1¾ × ¾	1	5	3–4·5V	2 or 3 × U7	2–2½	1·6	300	£8.19.6
Modelectric	Modelectric, 2 Hanover Gardens, London, SE11	Relayless tone	1 × 1 × 2½	1	5	9V (Rx.) 3V (Act.)	PP3 (Rx.) 2 × U7 (Act.)	3	(Rx.) 3·5 (Act.) 0·1	3·5 400	£8.7.6
Otarion O-21	Otarion Electronics, Post Rd., Ossining, New York, U.S.A.	Relayless tone	1½ × 1 × ¾ (caseless)	½	4	3V	2 × U7 or 3·6V DEAC	1½	4	360	$11.50
Pioneer (U.S.A.)	F. & M. Electronics, 153 Vermont St., N.E., Albuquerque, N.M., U.S.A.	Relayless tone	1½ × 1½ × ¾ (caseless)	¾	4	3V	2 × U7 or 3·6V DEAC	1⅜	4·8	250	$18.95
Silvertone (Australia)	Silvertone Electronics, 727 Princes Highway, Tempe, N.S.W., Australia	Relayless tone	2½ × 1½ × ¾	1½	Valve + 4	22·5V (HT) 1·5V (LT) 3–4·5V (Act.)	B122 (HT) U7 (LT) 2 or 3 × U7 (Act.)	4½	(HT) 0·95 (LT) 2·5 (Act.) —	6 2·5 450	£A12.19.6
Terrytone II (Kit) (British)	MacGregor Industries	Relayless tone	3 × 2 × ½ (caseless)	1½	4	4·5V	3 × U7 or 4·8V DEAC	2⅞	1	250	£5.19.6 (kit)
A.B.C. Mini-Sonic	A.B.C. Electronics, Oldham, Lancs.	Relayless tone	1¾ × 1½ × 1	1	4	4·5V	3 × U7	2½	2	410	£7.19.6
Futaba. F4–LR	Futaba. Japan	Relayless tone	1½ × 1 × ¾	¾	4	3V	2 × U7	1⅜	1	250	£7.19.6

RECEIVERS—SINGLE CHANNEL SUPER-REGENERATIVE, RELAYLESS (DUAL OUTPUT)

These operate standard escapements, and in addition provide "Quick Blip" trigger for motor control. Also operate magnetic proportional actuators

CS505A Finch II (U.S.A.)	C. & S. Distributors, 13400-12 Saticoy St., North Hollywood, U.S.A.	Relayless tone	1½ × 1¼ × ⅞ (caseless)	⅞	3	3V	2 × U7 or 3·6V DEAC	1½–2	Unknown		$16.50
Guidance System II (British)	Radio Control Specialists Ltd., National Works, Bath Rd., Hounslow, Middx.	Relayless tone	1⅝ × 1 1/16 × 1	1	5	4·5V	3 × U7 or 4·8V DEAC	2¼	1·8	380	£7.0.0
Otarion O-22 (U.S.A.)	Otarion Electronics, Post Rd., Ossining, New York, U.S.A.	Relayless tone	1½ × 1 × ⅝ (caseless)	⅝	5	3V	2 × U7 or 3·6V DEAC	1⅜	Unknown		$29.95 U.S.A.
Sportsmaster (U.S.A.)	Min-X Radio, 8714 Grand River Ave., Detroit 4, Mich., U.S.A.	Relayless tone	1 11/16 × 1⅛ × ⅝ (caseless)	1	5	3V	2 × U7 or 3·6V DEAC	2	6	300	£7,10.0

RECEIVERS—SINGLE CHANNEL SUPER-REGENERATIVE, RELAY

Capri (U.S.A.)	Min-X Radio	Relay tone	1 11/16 × 1 7/16 × 11/16	2	4	3V	2 × U7 or 3·6V DEAC	3	7·5	28	£12.10.0
Controlaire 4 (U.S.A.)	World Engines Inc., 8206 Blue Ash Road, Cincinnati, Ohio, U.S.A.	Relay tone	2 × 1 7/16 × ⅞	1⅞	4	3V	2 × U7 or 3·6V DEAC	2¾	3	50	$19·98 (ass.) $14·98 (kit) (U.S.A.)
CS503A Lark II (U.S.A.)	C. & S. Distributors	Relay tone	2⅛ × 1¼ × 1	1⅝	4	3V	2 × U7 or 3·6V DEAC	2⅝	6	48	$18.50 (U.S.A.)
Gemini (British)	Derritron Radio Ltd., Chapel Lane, High Wycombe, Bucks.	Relay tone	1⅞ × 1½ × 1¼	1½	6	4·5V	3 × U7 or 4·8V DEAC	3	1·7	50	£16.16.0 with transmitter
Hill MkII (British)	Harrogate Radio, 16 Regent Parade, Harrogate	Relay carrier	3⅛ × 1⅞ × 1⅝	3	—	30V (HT) 1·5V (LT)	B105 (HT) D18 (LT)	9	(HT) 0·4 (LT) 100	4 100	(kit)
Pixie (Japan)	Ogawa Model Mfg. Co., Hiranobaba, Higashisumiyoshi, Osaka, Japan	Relay tone	2¼ × 1¼ × 1¼	1½	4	9V	PP3	2½	3·5	22	£16.5.0 complete with transmitter
Saturn (U.S.A.)	F. & M. Electronics, 153 Vermont St., N.E., Albuquerque, N.M., U.S.A.	Relay tone	2 × 1 7/16 × ⅞	1⅜	4	3V	2 × U7 or 3·6V DEAC	2½	4	82	$29.95
Silvertone (Australia)	Silvertone Electronics, 727 Princes Highway, Tempe, N.S.W., Australia	Relay tone	2½ × 1⅜ × 1	2	Valve + 3	22·5V (HT) 1·5V (LT)	B122 (HT) U7 (LT)	3½	(HT) 1 (LT) 25	6	£A13.16.0
U.K.	Harrogate Radio Co.	Relay tone	2¼ × 1⅝ × 1½	2¼	Valve + 2	22·5V (HT) 1·5V (LT)	B122 (HT) U7 (LT)	4	(HT) 1 (LT) 30	6 30	Components sold separately
A.B.C. Mini-Sonic	A.B.C. Electronics, Oldham, Lancs.	Relay tone	2¼ × 1 7/16 × 1	2¼	4	9V	PP3	3½	—	—	£8.18.0

RECEIVERS—SINGLE CHANNEL SUPERHET

Due to the necessity carefully to match superhet receiver to transmitter it is recommended that superhet Rx. and Tx. be purchased together unless purchaser has the necessary electronic equipment to match up the two

C.S. 507S Oriole (U.S.A.)	C. & S. Electronics, 7377 Beverly Boulevard, Los Angeles 36, Cal., U.S.A.	Relay tone	2½ × 1⅜ × 1	2½	6	6V	4 × U7 or 6·25V DEAC	4½	13		$39.50
C.S. 508S Cardinal (U.S.A.)	C. & S. Electronics	Relay tone	3 × 1⅜ × 1	3	6	6V	4 × U7 or 6·25V DEAC	5	13		$39.50
Kraft SHI (U.S.A.)	Kraft Custom Radio Control, 2519 Lee Avenue, South El Monte, California, U.S.A.	Relay tone	1 × 1⅝ × 2⅜	2½	6	9V	PP3	3½			$29.95
R.C.S. 1 (British)	Radio Control Specialists, Ltd.	Relayless tone	3 × 1⅞ × 1 1/16	3	6	7·2V	5 × U7 or 7·2V DEAC	6	5·1	350	£24.0.0
R.S.H. (U.S.A.)	Citizenship Radio Corp., 810 East 64th St., Indianapolis, Indiana	Relayless tone	2 × 1¼ × ⅞ (caseless)	1¼	7	3–4·5V	2 or 3 × U7 or 3·6V DEAC	2½–2¾	5		$34.95 (U.S.A.)
SH-100 (U.S.A.)	World Engines Inc.	Relay tone	2 1/16 × 1 7/16 × 11/16	2½	6	3V	2 × U7 or 3·6V DEAC	3½	6	48	$24,98 (kit) $32.98 (ass.) (U.S.A.)
Superhet 1200 (U.S.A.)	Min-X Radio Inc.	Relay tone	3⅛ × 1⅝ × 1	3½	8	3V	2 × U7 or 3·6V DEAC	4½	6	35	£25.0.0
Vanguard (U.S.A.)	F. & M. Electronics, 153 Vermont St., N.E., Albuquerque, N.M., U.S.A.	Relay tone	2⅜ × 1⅝ × 1	2½	7	3V (3·2V max.)	2 × U7	2¾	10	58	$39.95
RMK Custom	MK—Japan	Relay tone	2½ × 1⅜ × 1	3	7	6V	4 × U7 or DEAC	5	7	26	£30 with Tx.
Futaba F6-STR	Futaba, Japan	Relay tone	2⅛ × 1⅜ × 1	2⅜	6	9V	PP3	—	10	21	£12.15.0
O.S. Minitron	O.S., Japan	Relay tone	2½ × 1¼ × 1	2⅜	6	6V	4 × U7 or DEAC	—	5	20	£31.9.7 with Tx.

Transmitter	Manufacturer	Type	Size (inches)	Wt. (oz.)
Astral (British)	Modelectric, 2 Hanover Gardens, London, SE11	Tone transistor	5½ × 3⅝ × 2¼	
Carrier Wave MkII (British)	MacGregor Industries, Station Wharf, Langley, Bucks.	Carrier wave (valve)	4 × 3 × 2½ (baseboard only)	3
Citizenship SPX (U.S.A.)	Citizenship Radio Corp., 810 East 64th St., Indianapolis, Indiana, U.S.A.	Tone transistor	6¼ × 3⅜ × 2⅞	30
Citizenship TTX (U.S.A.)	Citizenship Radio Corp.	Tone transistor	5½ × 3½ × 1⅞	12
Converter Modulator (British)	MacGregor Industries	Tone valve/transistor	7½ × 6 × 1⅞	36
Cougar I (U.S.A.)	Spacetron Inc., Box 84, Broadview, Illinois, U.S.A.	Tone transistor	5 × 4 11/16 × 1⅞	
C.S. 509 Falcon II (U.S.A.)	C. & S. Distributors, 13400-12 Saticoy St., North Hollywood, Cal., U.S.A.	Tone transistor	6 × 4 × 2	
Echo (U.S.A.)	F. & M. Electronics, 153 Vermont St., N.E., Albuquerque, N.M., U.S.A.	Tone transistor	7 × 4½ × 2⅞	39
Emco Ace (British)	Emco of Coventry, 62 Lower Ford St., Coventry	Tone valve	7⅞ × 6 × 2⅛	63
Gemini (British)	Derritron Radio Ltd., Chapel Rd., High Wycombe, Bucks.	Tone transistor	6⅜ × 3½ × 2¼	24
Guidance System II (British)	Radio Control Specialists, National Works, Bath Rd., Hounslow, Middx.	Tone transistor	5½ × 3½ × 2⅜	
Kraft Commander	Ace Radio Control, Box 301, Higginsville, Missouri, U.S.A.	Tone transistor	5 × 3½ × 2	
Kraft KT1 (U.S.A.)	Kraft Custom Radio Control, 2519 Lee Avenue, South El Monte, Cal., U.S.A.	Tone transistor	6 × 4⅜ × 2¼	
Mule II (U.S.A.) (kit)	World Engines Inc., 8206 Blue Ash Rd., Cincinnati, Ohio, U.S.A.	Tone transistor	6 × 4 × 2	28
Otarion O–31 (U.S.A.)	Otarion Electronics, Post Rd., Ossining, New York, U.S.A.	Tone transistor	6 × 3⅝ × 2	26
Pixie (Japan)	Ogawa Model Mfg. Co., Hiranobaba, Higashisumiyoshi, Osaka, Japan	Tone transistor	3⅜ × 2¼ × 1¼	6
Powermite TT1 (U.S.A.)	Min-X Radio Inc., 8714 Grand River Ave., Detroit, Mich., U.S.A.	Tone transistor	6½ × 4½ × 2¼	28
Powermite 1200K (U.S.A.)	Min-X Radio Inc.	Tone transistor	6½ × 4½ × 2¼	28
Pulsemite 1200 and 800 (U.S.A.)	Min-X Radio Inc.	Tone transistor pulse proportional	6½ × 5 × 2¼	32
Transistor Transmitter (British)	MacGregor Industries	Tone transistor	7 × 6¼ × 1⅞	30
Futaba, FT–5A	Futaba, Japan	Tone transistorised	6⅜ × 3 × 1⅜	20½
Futaba FT5A	Futaba, Japan	Tone transistorised	4⅜ × 2 5/16 × 1 1/16	9
Futaba FT5C	Futaba, Japan	Tone transistorised	5⅝ × 4 × 1½	17½
A.B.C. Mini-Sonic	A.B.C. Electronics	Tone transistorised	6 × 4½ × 2¼	34
O.S. Minitron	O.S., Japan	Tone transistorised	5½ × 3½ × 1⅞	22

Voltage	Batteries required (Ever Ready)	Aerial	Current drain (mA) Idle	Current drain (mA) Signal	Modulation %	Tone frequency c.p.s.	Price
18V	2 × PP7	53 in.	26·5	18·5	100	800	£11.9.9
HT 90–120V LT 1·5V	B135 AD4	48 in.	HT— LT 200	15 200	—	—	£2.19.6
9V	PP9	Off centre loaded		60	100		$39.95 (U.S.A.)
9V		36 in. off centre loaded			100		$29.95 (U.S.A.)
HT 9V LT 1·5V	2 × 1289 AD35	39½ in.	HT — LT 100	290 100	90	450	£8.19.6
9V	PP9		30		90–100	700	$34.95 (U.S.A.)
9V	PP9	55 in. centre loaded			85	800	$24.50 $21.50 (kit)
6V	Lantern battery	54 in.	180	200	95	580	$29.95
HT 135V LT 1·5V	2 × B101 AD35	28½ in.	HT — LT 200	14 200		1,100	£11.19.6. Complete with receiver
9V	PP9	48 in. centre loaded	21	16	100	850 or 3,200	£18.14.3 (relayless) £19.7.3 (relay) Tx. and Rx.
12V	2 × PP1	44 in. centre loaded	44	34	100	500	£7.0.0
9V	PP9	54 in.			100	500	$17.95 (U.S.A.)
9V	PP9	56 in.			100	500	$29.95 (U.S.A.)
9V	PP9	48 in. centre loaded	45	45	97	700	$29.98 (U.S.A.) (kit)
18V	2 × PP9	42 in.	36	52	100	600	$39.95 (U.S.A.)
9V	PP3	36 in. centre loaded	48	50	100	800	£16.5.0. Complete with receiver
9V	PP9	24 in. centre loaded	48	50	100	800	£15.0.0
9V	PP9	24 in. centre loaded	48	50	90–95	1,200	£15.0.0
9V	PP9	24 in. centre loaded	56	48	90–95	1,200 or 800	£30.0.0
18V	4 × 1289	48 in.	36	55	90	590	£10.19.6
12V	8 × U7 pen cells	32½ in.	40	82	—	420	£18.19.0
12V	8 × U7 pen cells	37	6·5	30	—	420	£8.5.0
12V	8 × U7 pen cells	53	55	110	—	550	£15.10.0
12V	2 × PP1	44	45	30	—	465	£10.9.6
12V	8 × U7 pen cells	46	47	78	—	560	£31.9.7 with Rx.

Escapement	Manufacturer	Type	Functions	Size (inches)	Wt. (oz.)	Voltage	Coil resistance (ohms)	Price
Babcock MkII Super-compound (U.S.A.)	Babcock Controls Inc., 20762 Laguna Canyon Rd., P.O. Box 666, Laguna Beach, California, U.S.A.	Compound selective	Left and right rudder, up elevator, plus "quick-blip" to throttle escapement	1⅞ × 2½ × 1	⅞	3–4·5V	7	
Babcock MkV Hyper-compound (U.S.A.)	Babcock Controls Inc.,	Compound selective	Right and left rudder, up and down elevator, plus "quick-blip" trigger to throttle escapement	1⅞ × 2½ × 1	⅞	3–4·5V	7	
Babcock EMI (U.S.A.)	Babcock Controls Inc.,	Sequential	Two position throttle control	1⅞ × 1 × 1		3–4·5V	7	£3.19.6
Bonner SN (U.S.A.)	Bonner Specialities Inc., 9522 W. Jefferson Blvd., Culver City, California, U.S.A.	Sequential sel neutralising	Left-neutral-right-neutral sequence for rudder or fast-slow throttle control	1½ × 1½ × 1	⅞	3–4·5V	8	£4.9.6
Conquest (British)	Scorpion Precision Products Ltd., Elmic Works, Gallows Corner, Southend Arterial Rd., Romford, Essex	Sequential self neutralising	Left and right rudder or fast and slow throttle according to application	1⅞ × ⅞ × 1	⅞	3–4·5V	11·5	£1.15.0
Commander (British)	Ditto	Compound selective	Left and right for rudder: "quick-blip" to Corporal throttle escapement	1⅝ × 1½ × ⅞	⅞	3–4·5V	11·5	£2.19.2
Corporal	Ditto	Sequential	Two position action for throttle control	2⅛ × 1½ × ⅞	⅞	3–4·5V	11·5	£2.7.4
Compact	Ditto	Compound selective	Left and right rudder, up elevator, plus "quick-blip" trigger to throttle escapement (Corporal)	1⅞ × 1⅞ × 1	0·8	3–4·5V	8	£3.7.4
O.S. Minitron K1 (Japan)	Ogawa Model Mfg. Co., Hiranababa, Higashisumiyoshi, Osaka, Japan	Compound selective	Left and right rudder, plus third position trigger for throttle escapement	1⅞ × 1⅞ × 1		3–6V	10	£2.16.3
O.S. Minitron S2 (Japan)	Ogawa Model Mfg. Co.,	Sequential	Two positions for fast and slow speed throttle control	1⅞ × 1 × 1⅞		3–6V	10	£2.7.4
O.S. Minitron S4 (Japan)	Ogawa Model Mfg. Co.,	Sequential. Four positions in progression	Four positions providing fast, intermediate, slow, intermediate, etc., throttle functions in progression	1⅞ × 1 × 1⅞		3–6V	10	£2.0.4
Rising 2 Pawl Clockwork (British)	Rising & Schultz, Central Garage, Whissendine, Nr. Oakham, Rutland	Sequential. Two position self neutralising	Left and right rudder in sequence or fast and slow throttle according to application	1⅞ × 1½ × ⅞	1½	4·5–6V	7	£2.1.4
Rising 4 Pawl Clockwork (British)	Rising & Schultz,	Sqeuential	Holds four positions in sequential progression for fast, intermediate, slow, intermediate etc., throttle functions	1⅞ × 1½ × ⅞	1⅞	4·5–6V	7	£2.4.3
Rising Lightweight S/N (British)	Rising & Schultz,	Two position sequential self neutralising	Right-neutral-left-neutral sequence or fast and slow throttle positions according to application	1½ × 1⅞ × ⅞	½	4·5–6V	7	£1.5.3
Rising Compound (British)	Rising & Schultz,	Compound selective	Left and right rudder plus "quick-blip" trigger to throttle escapement using relay back-contact, or relayless double ended output Rx	2⅛ × 1½ × ⅞	1	4·5–6V	7	£2.9.11
PSN-2 (U.S.A.)	Citizenship Radio Corp., 810 East 64th St., Indianapolis, Indiana, U.S.A.	Sequential self neutralising	Left and right rudder or fast and slow throttle according to application	⅞ × ⅞ × ⅞	⅞	3–4·5V	9	$3.95 (U.S.A.)
SE-2 (U.S.A.)	Citizenship Radio Corp.,	Selective	Left and right rudder	1⅝ × 1⅞ × ⅞	⅞	3–4·5V	9	$7·95 (U.S.A.)
SE-2M (U.S.A.)	Citizenship Radio Corp.,	Compound selective	Left and right rudder plus "quick-blip" trigger to throttle escapement (PSN-2)		1⅝	3–4·5V	9	$12.95 (U.S.A.)
Varicomp (U.S.A.)	Bonner Specialities Inc.,	Compound selective	Left and right rudder, plus "quick-blip" trigger to throttle escapement	2⅛ × 1½ × 1½	1⅝	3–4·5V	8	$8.95 (U.S.A.)
Varicomp RE (U.S.A.)	Bonner Specialities Inc.,	Compound selective	Left and right rudder, up elevator, plus "quick-blip" trigger to throttle escapement	2⅛ × 1½ × 1⅞	1½	3–4·5V	8	$9.75 (U.S.A.)

Servo	Manufacturer	Type	Functions	Size (inches)	Wt. (oz.)	Voltage	Current drain (mA)	Price
Atlas PCS-100 (U.S.A.)	Don Sceeb Inc., 955 Milsteed Way, Rochester, New York, U.S.A.	Selective. Relay operated	Left and right rudder, self neutralising	2⅛ × 1 7/16 × 1 1/16	2			$12.95 (U.S.A.)
Metz 190/18 (West Germany)	Metz Apparatewerke, Furth/Bayern, West Germany	Selective. Relay operated	Left and right rudder, self neutralising	2¼ × 1½ × 1½	2¼	6V	400	
Minicombo (West Germany)	Alexander Engel	Sequential. Relay operated	Left-neutral-right-neutral in progression	2 × 1½ × 1⅞	1½	1·5V + 1·5V or 3V + 3V	400 or 600	£2.0.11
Minicombo II (West Germany)	Alexander Engel	Selective. Relay operated	Left and right rudder in selective sequence, self neutralising	2 × 1½ × 1⅞	1½	1·5V + 1·5V or 3V + 3V	400 or 600	£2.4.10
RI (Germany)	Robbe, 6421 Metzlos-Geheiag, W. Germany	Sequential. Relay operated	Left-neutral-right-neutral in progression	2⅛ × 1⅜ × 1	1·85	4·5V–6V	125	
RMK Dynamite (Japan)	Kato Model Aircraft Co., 7, 4-chome, Hattori-Honmachi, Toyonaka, Osaka, Japan	Selective. Relay operated	Left and right rudder in selective sequence. Self neutralising, plus third position trigger to secondary Type 7A throttle control	2 × 1¼ × 1⅜	1·9	1·5V + 1·5V	120	£4.9.6
RMK Dynamo (Japan)	Kato Model Aircraft Co.,	Three position sequential	Three progressive positions to provide fast, intermediate and slow throttle control	2⅜ × 1⅜ × 1	1⅜	1·5V	120	£4.3.6
Slim Jim (British)	Modelectric, 2 Hanover Gardens, London, SE11	Selective. Relay operated	Left and right rudder in selective sequence, plus third position trigger to secondary unit for throttle control	2⅛ × 2¼ × ⅞	1	4·5V	140	£3.10.0
Slim Jim Relayless (British)	Modelectric,	Selective. Relayless operation and sequentia	Left and right rudder in selective sequence, plus third position trigger to secondary unit for throttle control	2⅛ × 2⅜ × ⅞	1·2	4·5V	140–400	Selective £4.15.0 Sequential £3.8.0
Unimatic (Germany)	Johannes Graupner, Kirchhiem/Teck, West Germany	Selective, sequential or cascaded unit	1. Selective left and right rudder with third position impulse to cascaded throttle unit. 2. Sequential left-neutral-right-neutral. 3. Cascaded uniform selective Unimatic	2⅛ × ⅞ × 1½	2	2·4–3V		£3.19.6
Unimite (British)	C. & L. Developments Ltd., 47 Queens Rd., Weybridge, Surrey	Selective or cascaded unit	Selective left and right rudder with "quick-blip" trigger to second Unimite for three position throttle	2 11/16 × 1 5/16 × 1 5/16	1½	4·5V	400	£3.10.0
Unipack (British)	C. & L. Developments Ltd.,	Twin servo installation pack	Selective left and right rudder, plus three position throttle triggered by "quick-blip" impulse	4¼ × 2⅜ × 1⅜	4·5	4·5V	400	£11.11.0

D.E.A.C. BATTERIES

DEAC batteries are sealed nickel-cadmium accumulators available either as single cells or made-up battery units of one, two, three, four, etc., cells welded together. Type DK cells are now obsolete but are still obtainable. Data are given for single cells only in these type numbers.
Type DKZ cells are the current production sizes in most popular demand for radio control work. Made-up battery units are fitted with welded on "snap" terminals to take standard battery press studs. Made-up battery packs are sheathed with a plastic sleeve.
DEAC batteries may be taken as needing recharging when the voltage drops to 1.1 volts per cell. DEAC batteries should never be discharged below 1.0 volts per cell.

Type No.	No. of Cells	Nominal Voltage	Capacity Milliampere/ hours at 10 hour rate	Design Discharge Current milliamps	Safe Maximum Discharge Current milliamps	Dimensions Dia. ins.	Dimensions Height ins.	Weight ounces	Recommended Charging Current (14 hours for full charge)
20 DK	1	1·2	20	2	20	—	—	—	2 milliamps
50 DK	1	1·2	50	5	50	·61	·23	·15	5 milliamps
100 DK	1	1·2	100	10	100	1	·23	·32	10 milliamps
150 DK	1	1·2	150	15	150	1	·26	·40	15 milliamps
225 DK	1	1·2	225	22·5	225	1	·35	·44	25 milliamps
450 DK	1	1·2	450	45	450	1·7	·28	1·16	50 milliamps
225 DKZ	1	1·2	250	22·5	250	1	·36	½	25 milliamps
	2	2·4	250			1	·72	1	
	3	3·6	250			1	1·1	1½	
	4	4·8	250			1	1·45	2	
	5	6·0	250			1	1·8	2½	
	6	7·2	250			1	2·15	3	
500 DKZ	1	1·2	500	50	500	1·7	·39	1	50 milliamps
	2	2·4	500			1·7	·75	2	
	3	3·6	500			1·7	1·15	3	
	4	4·8	500			1·7	1·9	4	
	5	6·0	500			1·7	1·9	5	
	6	7·2	500			1·7	2·3	6	